Final Report

DEVELOP, REFINE, AND VALIDATE A SURVEY TO ASSESS ADULT'S PERSPECTIVES OF AUTONOMOUS RIDE-SHARING SERVICES

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16. Abstract

Autonomous vehicles (AVs) have generated great excitement for the future of transportation. Not only are self-driving cars already being piloted, but there is also significant interest and investment in shared automated transportation services by companies such as Uber, Lyft, and Voyage (Isaac, 2017). Despite the excitement, there is much uncertainty regarding their level of acceptance and adoption by the general public. Due to the lack of field data, it is currently extremely difficult to assess the acceptance and adoption practices of the population towards this “disruptive technology” (Bansal & Kockelman, 2017). In addition to demand-side factors (e.g., willingness to pay) and supply-side factors (e.g., technology prices), the perception of the end users must be considered. While there have been several surveys on user perception of AVs, most of them have focused on general public opinion of perceived benefits and concerns of AVs, and they are not directly tied to a field implementation of AVs (Bagloee et al., 2016). Experience and exposure to new technology affect adults’ perceptions and level of technology acceptance. As such, survey items were developed to assess whether adults’ potential exposure to the AV will be positive or negative. Furthermore, survey psychometrics were established to ensure that the FDOT Autonomous RideShare Services Survey (ARSSS) is a valid and reliable tool for assessing adults’ perceptions of AVs. Moreover, the interaction of AVs, especially those used in shared mobility services, were examined from the perspective of how they interact with other automobiles, bicyclists, and pedestrians – as leaders and as followers. Such behaviors of the AV and other road users were interpreted in terms of the design characteristics of the route for an Autonomous Vehicle Shuttle (AVS) at Lake Nona, FL. The survey and understanding AV–road-user behavior – two critical aspects of this project – are necessary for informing the acceptance and adoption practices among users of these AV technologies.

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EXECUTIVE SUMMARY

Autonomous vehicles (AVs) have generated great excitement surrounding the future of transportation. Not only are self-driving cars already being pilot-tested (Davies, 2017), but there is also significant interest and investment in shared autonomous transportation services by companies such as Uber, Lyft, Voyage, and others (Isaac, 2017). Despite the excitement, there is much uncertainty regarding their level of acceptance and adoption by the general public. Due to the lack of field data, it is currently extremely difficult to assess the rate of adoption of such a disruptive technology (Bansal & Kockelman, 2017). In addition to demand-side factors (e.g., willingness to pay) and supply-side factors (e.g., technology prices), the perception of the end users must be taken into account.

The "baby boomers" started to turn 65 in 2011, and the median age of the country was 37.9 years in 2016 (U.S. Census Bureau, 2017). As the baby boomers continue to age, many of them will stop driving altogether. Older adults make up close to a quarter of the U.S. population (U.S. Census Bureau, 2017) and may be one of the best target populations for early adoption of autonomous vehicle technology. Benefits of adopting AVs include prolonged mobility, accessibility, community involvement, and, eventually, safer roadways.

While there have been several surveys on user perception of autonomous vehicles, most of them have focused on generic public opinion of perceived benefits and concerns of AVs, and they are not directly tied to a field implementation of AVs (Bagloee et al., 2016). Experiences and exposure to new technology affect (older) adults' perceptions and level of technology acceptance (https://dl.acm.org/citation.cfm?id=2093697). As such, survey items were developed to assess whether older adults' potential exposure will be positive or negative. This is critical for informing acceptance and adoption of such AV technologies.

The Florida Department of Transportation (FDOT) commissioned a study on general perception of AVs by older adults in 2015 (Duncan et al., 2015). The study showed that even though older adults are less likely to trust AVs, over half of the respondents were interested in AVs. The University of Florida has also developed a survey on the perceptions of older adults, necessary for understanding their adoption practices of AV technologies. Building on this foundational work, the team with expertise in this area, in combination with new approaches (evidence-based literature review, evaluating other current AV technology user surveys for item cross-checking, focus group methodologies, content validity indexes and psychometric testing) has further developed, refined and tested the FDOT Autonomous RideShare Services Survey (ARSSS).

This project supports the goals of FDOT's Safe Mobility for Life Program and Coalition (SMFLC) as they work to implement Florida's Aging Road User Strategic Safety Plan (ARUSSP). This project addresses Strategy 6.1.6 in the "Transitioning from Driving" Focus Area of the ARUSSP: "Determine impact of AVs on aging road user mobility and begin developing information and materials to educate users about this new technology." Results from this project will provide vital foundational knowledge to inform the SMFLC as they work to develop educational materials to help address AVs as a transportation option for older adults across the state.

Moreover, the interaction of AVs, especially those used in shared mobility services were examined from the perspective of how they interact with other automobiles, bicyclists, and pedestrians – as leaders and as followers. Using video technology, such behaviors of the AV and other road users were interpreted in terms of the design characteristics of the route for an Autonomous Vehicle Shuttle (AVS) at Lake Nona, FL. The survey and AV road-user behavior – two critical aspects of this project – are further necessary for informing the acceptance and adoption practices among users of these AV technologies.

The implications and next steps of this project – This survey development provides a unique opportunity to study the perception and acceptance of AV technology (i.e., autonomous ride sharing services such as the autonomous shuttle) by adults, via the ARSSS – a reliable and validated instrument. Field data collected from an autonomous shuttle (Beep) operating in Lake Nona exemplify important road user behaviors interpreted within the design features of the road. Both the survey results and field data from the shuttle operations will support the SMFLC as it develops materials to educate older adults on the use of AVs as a transportation option for independent community mobility.

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1 INTRODUCTION

1.1 Background

In 2018, in the U.S. alone, over 6,900 older drivers (≥65 years old) died and more than 275,000 were injured as a result of motor vehicle crashes (National Center for Statistics and Analysis, 2020). This number amounts to nearly 20 older drivers being killed and 712 injured every day (National Center for Injury Prevention and Control, 2017). Florida is leading the nation, with almost 25% of the population being older adults. Unfortunately, 2016 crash statistics indicate that out of the 71,247 older drivers that were involved in a crash, 20,395 were injured, and 358 died (Federal Highway Administration, 2016). Despite older drivers adhering to safe driving practices, including using seat belts, driving under safe conditions, and avoiding driving under the influence of alcohol (National Highway Traffic Safety Administration, 2016; National Highway Traffic Safety Administration, 2017B; Naumann et al., 2010; Quinlan et al., 2004), their increased risk for death or injury in motor vehicle crashes stems from age-related declines in visual, cognitive, and motor functions that impact their ability to drive safely (Owsley, 1999). Age-related declines impair older drivers' performance, including the ability to control a vehicle while conforming to the rules of the road, declines in vision and reaction times, and decreased function in working memory (Centers for Disease Control and Prevention, 2017; Owsley, 1999; Transportation Research Board, 2016). These factors also include or may be exacerbated by comorbidities, polypharmacy, and frailty (i.e., decreased bone mineral density). As a result, older drivers face increased risk for crashes, crash-related injuries, and/or fatalities (Centers for Disease Control and Prevention, 2017; National Highway Traffic Safety Administration, 2015). Older drivers are the second most prevalent group involved in motor vehicle collisions in the U.S. (Centers for Disease Control and Prevention, 2017; National Highway Traffic Safety Administration, 2015). Yet studies associate mobility afforded by driving with increased life satisfaction, quality of life, autonomy, and well-being for older drivers (Dickerson et al., 2014; Dickerson et al., 2017A; Dickerson et al., 2017B; Musselwhite, 2011). In contrast, driving cessation is associated with poor health trajectories, including increased rates of depression, limited life-space mobility, early nursing home admissions, and premature death (Dickerson et al., 2014; Dickerson et al., 2017A; Dickerson et al., 2017B; Musselwhite, 2011).

As the number of adults over 50 years of age increases in the U.S., *crash mitigation strategies* emerge as a critical factor in preventing crashes and associated impacts on traffic congestion. Moreover, such mitigation strategies, i.e., older driver screening, assessment, intervention (Classen et al., 2012; Classen et al., 2014; Dickerson et al., 2014), enhanced vehicle with improved safety features (Bengler et al., 2014; Centers for Disease Control and Prevention, 2015; Charlton et al., 2002; Koppel et al., 2013; National Highway Transportation Safety Administration, 2007), enhanced infrastructure (Classen et al., 2009; Shechtman et al., 2007, 2008) and policies (Classen & Awadzi, 2008; Levy, 1995; Morrisey & Grabowski, 2005; Staplin & Freund, 2013), allow older drivers to stay on the road – longer and more safely, while they reap the health-related benefits of being actively engaged in their communities and participating in societal events. Public health benefits are also evident as the risk for other motorists or road users being crash-involved with older drivers is reduced.

Autonomous vehicles (AVs) (Society of Automotive Engineers International, 2016), now becoming a reality, have enormous safety, societal, and environmental benefits. Particularly, AVs can prevent older driver crashes occurring due to age-related declines in function resulting in human error and can enhance lifelong mobility while also reducing pollution and *non-recurrent congestion impacts* because of crash reduction (National Highway Traffic Safety Administration, 2013, 2017A). An enacted bill (HB 7061) in the Florida legislature requires that Long Range Transportation Plans in the state include advanced technologies such as AVs. However, based on recent studies examining consumer preferences of AVs, older adults indicated that trust and hesitation exist around their comfort in adopting full vehicle automation (American Automobile Association, 2016; Hartford, 2015; Reimer, 2014). A weakness of these studies is that surveys used to assess users' perceptions have not been properly validated nor shown to be reliable.

1.2 Objectives

The objectives of this project are as follows:

Objective 1: Develop an initial draft survey.

Items for this survey were developed from recent literature on older adults and their adoption practices towards technology, as well as from user surveys (Buckley et al. 2018; Hutchins & Hook, 2017; Madigan et al., 2016; Nordhoff et al., 2016; Osswald et al., 2012; Panagiotopoulos & Dimitrakopoulos, 2018), the Technology Acceptance Model (Davis, 1989), the Technology Readiness Index 2.0 (Parasuraman & Colby, 2015), and the Life Space Questionnaire (Stalvey et al., 1999) (which captures when, where, how far, how, and why older adults venture from their primary dwelling). We included items from the FDOT and FSU survey (Duncan et al., 2015) and other national surveys of relevance (Abraham et al., 2016; Brookings Institution, 2018; Choi & Ji, 2015; Elefteriadou et al., 2019; Hutchins & Hook, 2017; Schoettle & Sivak, 2014). Thus, on the basis of the literature, theoretical frameworks, existing surveys, and guided by measurement theory, we developed items capturing the notion of older adult perceptions on acceptance and adoption practices of AV technologies pertaining to autonomous modes of transportation. Then, contained in a draft survey, the University of Florida Survey Research Center (FSRC: http://flsurveyresearch.center.ufl.edu/fsrc-services/) conducted focus groups, with a diverse group of stakeholders (e.g., SMFLC) and participants over the age of 50, to further determine participant perspectives and to refine and expand the item pool of the survey.

Objective 2: Develop a beta version of the survey for adequate face validity.

Face validity indicates that a measure is testing what it is supposed to and that the items are viewed as plausible (Jenkinson et al., 1996). No statistical analysis is involved in this process, and the measure was reviewed by the layperson to determine plausibility and understandability of the items. For example, when developing the items, content reviewers rated the survey items on their ease of reading, content, clarity, appropriateness, and length of survey.

Objective 3: Refine the survey based on the feedback of expert reviewers.

Content validity depends on the extent to which an empirical measure reflects a specific domain of content. Following the guidelines of Lynn (1986), we invited subject-matter experts to complete a *content validity index* (CVI) – an index of consensus related to the relevance of each of the items in the survey. Apart from rating each of the items on a 4-point Likert scale (1 = not relevant, 2 = relevant with major revisions, 3 = relevant with minor revisions, and 4 = very relevant), experts also gave feedback on item accuracy, purpose, organization, clarity, appearance, understandability, and adequacy (Grant & Davis, 1997). Content validity can be claimed if the rater agreement on the item relevance is 80% or higher (House et al., 1981).

Objective 4: Ensure the survey is reliable (test-retest) and valid (construct validity).

Reliability pertains to the reproducibility of test results and the amount of variation measured that is real and not due to error. Reliability, generally, is based on a correlation coefficient or a measure of agreement and is referred to as a reliability coefficient, which can range from 0 to 1 (0 = no reliability and 1 = perfect reliability). The test-retest method estimates the reliability or stability of measurements when the same test is given to the same people initially and after a specified period of time. One obtains a correlation between scores on the two administrations of the same test. Although the assumption is that responses to the test and retest will correlate because they reflect the same true score, the correlation of measurements across time will be less than perfect due to the transient nature of human perception. This may also occur because of *instability* of measurements taken over various time points (Carmines & Zeller, 1979; Portney & Watkins, 2009).

Construct validity establishes whether the assessment measures a construct and the theoretical components underlying the construct. A construct is a concept and construct validity is the level of agreeance between observations (i.e., participants' response) and theory. The process of establishing construct validity involves at least three steps (Carmines & Zeller, 1979):

1. Determine the theoretical relationship between the items themselves.
2. Determine the empirical relationship between the item measures.
3. Interpret the empirical evidence to clarify the construct validity of the survey.

We used all three of these methods to assess the construct validity of the survey. This is a critical step for evidence-based informed decision making.

Objective 5: Disseminate the information on survey development.

Dissemination focuses on the targeted distribution of information and implementation, as well as documenting the process underlying the dissemination and implementation (Grimshaw et al. 2012). Effective dissemination is critical to ensure that stakeholders involved in AV technology research, policy, or practice accept the evidence underpinning the creation and refinement of the survey (Scott et al., 2012). Through dissemination science, we decreased the research-practice gap by targeting clinicians most involved with late adulthood and older drivers and informing them of the survey as a validated decision-making tool. We coordinated these efforts with the credible partnering of our own professional networks (e.g., conference presentations at American Occupational Therapy Association, Transportation Research Board) and scientific communities (peer-reviewed publications in credible journals), as well as through our FDOT advocacy groups. Through such messaging, we optimized the use of the survey as a foundational tool to understand user acceptance and adoption of AV technology.

1.3 Research Approach

To meet the objectives of this project, the research was collated into tasks, summarized below:

- Task 1 – The Institute for Mobility, Activity and Participation (I-MAP) and the FSRC developed an initial draft survey. A three-pronged approach (see, Tasks 1.a, 1.b, and 1.c) was used to develop the initial draft survey.

    - Task 1.a – I-MAP reviewed existing literature (Abraham et al., 2017; Bagloee et al., 2016; Bansal et al., 2016; Fagnant & Kockelman, 2015; Haboucha et al. 2017; Madigan et al., 2016; Penmetsa et al., 2019; Petersen et al., 2019; Shen & Neyens, 2017) and technology acceptance models (Buckley et al., 2018; Hutchins & Hook, 2017; Madigan et al., 2016; Nordhoff et al., 2016; Osswald et al., 2012; Panagiotopoulos & Dimitrakopoulos, 2018) to guide construction of the draft survey for relevant items assessing the transportation users' perceptions of AVs. Using an evidence-based search strategy in conjunction with the seminal technology acceptance models, we identified items that reflected older users' perceptions of AVs and advanced driver assistance systems (ADAS). Perceptions were operationalized as *perceived usefulness, perceived ease of use, intention to use, safety, trust, affordability, control and driving, accessibility, and social influences*. An evidence-based item pool representative of the literature and the technology acceptance models was developed.

    - Task 1.b – I-MAP extracted survey items from a survey developed by our colleagues at FSU and the SMFLC (Duncan et al., 2015) and other relevant national surveys (Abraham et al., 2016; Choi & Ji, 2015; Hutchins & Hook, 2017; Schoettle & Sivak, 2014) to enhance the item pool from Task 1.a.

- Task 1.c – Further develop and reduce the number of items in the item pool for older adults (≥50 years old). Task 1.c was an iterative process between the Project Manager, FSRC, I-MAP, and the SMFLC.
  - Subtask 1.c.1 – The FSRC revised survey items for clarity of language in questions and responses, using best survey practices and academic literature. The Project Manager then provided demographic survey items to be included in the final survey. The FSRC sent the revised item pool to the SMFLC. SMFLC members provided feedback on the item pool, suggesting which items to eliminate, keep, or revise. The FSRC received this feedback and revised the language, order, and response structure based on the constructive recommendations of the reviewers.
  - Subtask 1.c.2 – The FSRC conducted two virtual focus groups via Zoom, in which the participants provided additional feedback on the list of survey items. One focus group included Lake Nona residents whereas the other focus group consisted of individuals from rural areas surrounding Melrose, FL. The focus groups included no more than five individuals each so that there was effective communication with the moderator and among the other participants to obtain the synergy of group interaction. Feedback from the focus groups was provided to the Project Manager.
  - Subtask 1.c.3 – Feedback from the Project Manager was then integrated into the survey by members from I-MAP and FSRC.

- Task 2 – Using the draft survey developed in Task 1, a beta version of the survey was developed via face validity testing. The FSRC conducted a series of virtual focus groups with members from those groups defined in Task 1.c. Feedback from these groups allowed face validity of the survey to be established and, as such, ultimately contribute to enhancing the internal validity of the survey (Jenkinson et al., 1996). Specifically, we solicited feedback on the wording, meaning, clarity, credibility, and understandability of the items in the survey to ensure comprehension at an eighth-grade reading level.

- Task 3 – Establish the content validity of the beta version of the survey. We utilized ten subject-matter experts, with expertise in rehabilitation science, traffic engineering, human factors, gerontology, psychology, transportation planning, and mobility as a service. The subject-matter experts rated items for their relevance to provide a CVI for each item and the overall survey (Grant & Davis, 1997). The literature suggests that a minimum of six experts are adequate for establishing a CVI (Polit & Beck, 2006). The survey underwent two sets of reviews, each necessitating refinement, to ensure an excellent congruence

(≥80%) among the subject-matter experts (Polit & Beck, 2006). While establishing content validity, it was necessary to remove and refine items.

- Task 4 – Establish psychometrics, specifically, test-retest reliability (i.e., repeatability) and construct validity (i.e., measure construct/domain in question) of the AV Technology Survey. The survey was sent to a diverse sample of participants via Amazon Mechanical Turk (MTurk: https://www.mturk.com/), a validated method to conduct aging and behavioral research (Stothart et al., 2015). MTurk offers access to over half a million participants from 190 countries and can be helpful in expanding generalizability from the current project compared to typical research which oversamples the Caucasian, affluent, undergraduate population (Paolacci & Chandler, 2014).

    - Task 4.a – Examine internal consistency and test-retest reliability to improve survey reliability. Surveys were conducted twice by the same group of MTurk workers, with an interval of two weeks between tests. Internal consistency and test-retest reliability was analyzed by Cronbach's alpha coefficient and Spearman's rank correlation coefficient, respectively, using RStudio (R version 4.0.2) and the psych package.

    - Task 4.b – Examine items and factor loading to improve the construct validity of the AV Technology Survey (Anderson & Gerbing, 1988). During item development, dimensions were proposed based on previous research and AV-related technology acceptance models. Exploratory factor analysis was performed to inspect the factor structure, represented by items on the survey; and then a confirmatory factor analysis was employed to verify the dimensions and factors represented by items on the survey. The analysis further refined our survey by indicating redundant items and developing dimension scores created by grouping items that represent a shared factor or construct. We used RStudio (R version 4.0.2) and the lavaan package to complete these analyses.

- Task 5 – Evaluation of traffic operational and design interactions of the AV shuttle at Lake Nona (I-STREET). This task was conducted in parallel with Tasks 2, 3, and 4. In this task, we evaluated how the AV shuttle at Lake Nona (developed and operated by Beep; Figure 1-1) interacted with other automobiles, as leader and as follower. We also evaluated how pedestrians, bicycles, and scooters operated around it and how the AV detects and reacts to these road users. We related these behaviors to design characteristics along the arterial, if feasible. The extent of such analysis depends on the variability of design characteristics along the corridor the AV travels. Videos were collected from inside the vehicle showing the area in front of the vehicle. We compared operations without the shuttle to operations with the shuttle (headways, pedestrian behavior, etc.) and used video data to monitor interactions of the vehicle as it traveled along the route. We also collected design characteristics along the corridor in order to associate specific behaviors to specific design characteristics.

Figure 1-1. Beep AV shuttle route (Source: https://www.go-beep.com/move-nona)

2 DEVELOP ITEM POOL

This study was exempted by the University of Florida's Institutional Review Board (IRB201903309). All participants in the focus groups and on Amazon Mechanical Turk (MTurk) provided their written consent or waived consent to participate in the study. To complete Task 1.a, team members reviewed the literature for surveys examining older adults' perceptions (*perceived usefulness, perceived ease of use, intention to use, safety, trust, affordability, control and driving, accessibility, and social influences*) of AVs. Ninety-three items were extracted from the literature, and 39 items were generated that were not discussed or not present in the literature (e.g., ridesharing, ridehailing, automated taxis, automated shuttles). Some items extracted from the technology acceptance literature were adapted to focus on AVs. Twelve items were split to provide greater clarity to the question and answers. An item pool consisting of 144 items was created and reviewed by all team members.

The research team extracted 17 items from the Florida State University and Florida Department of Transportation's Safe Mobility for Life Program for Task 1.b. The item pool of 144 items from Task 1.a was combined with the 17 items from Task 1.b and were further reviewed and refined by all team members, resulting in a first draft pool of 161 items. The initial phase of the project identified a large number of survey items from the literature. This number of survey items was too large to be included in an operational survey instrument. The purpose of Task 1.c was to reduce the 161 items to approximately 50 items. For Subtask 1.c.1, the research team met and reduced 161 survey items to 54 items. The SMFLC reviewed the 54 items and provided substantive feedback resulting in the modification of 30 survey items, removal of 4 survey items, addition of 1 survey item, and pictures of transportation options relevant to the survey. The FSRC conducted two virtual focus groups (Subtask 1.c.2.) with residents in Lake Nona, FL, and Melrose, FL, via a videotelephony software program (i.e., Zoom). Focus groups were conducted online in response to the pandemic to prevent unwarranted risk to the research team and older participants. Each focus group consisted of five adults (i.e., one younger adult and four older adults) and was moderated by a survey development expert from the FSRC. Notes were taken during the meeting by another member of the team. Participants in the focus groups provided feedback on the wording, meaning, clarity, credibility, and understandability of the items in the survey to remove jargon and promote comprehension at an eighth-grade reading level. This feedback was sent to the FDOT Project Manager, and the Project Manager provided additional recommendations, edits, and comments to be included in the draft survey. I-MAP and FSRC members integrated feedback from the focus groups and Project Manager, which resulted in the completion of Subtask 1.c.3.

3 ESTABLISH FACE VALIDITY OF THE SURVEY

The FSRC conducted a series of virtual focus groups with members from the groups defined in Task 1.c. Feedback was solicited pertaining to wording, meaning, clarity, credibility, and understandability of the items in the draft survey, previously submitted as deliverable 1.c.3, with a goal of comprehension at an eighth-grade reading level. The focus group sessions were transcribed and then analyzed thematically with NVivo qualitative analysis software, using the categories noted above (wording, meaning, clarity, credibility, and understandability). The most common input from participants (coded as "nodes" in the analysis program) related to question wording, followed by clarity and meaning, and then understandability. Participant comments were also recorded by an I-MAP member during the focus groups, which operationalized participants' feedback to clarify wording, remove some items, make items clear or concise, and increase the understandability of the survey. During this process, feedback led to the modification of 22 (43%) of the 51 items. Furthermore, definitions of transportation options were modified to align with the survey and the pictures provided at the introductory section of each portion of the survey. Complexity and redundancy, in particular, were addressed in the revised beta version of the survey.

Microsoft Word was used to assess the survey's readability scores. The readability score (i.e., Flesch Reading Ease Score) is calculated based on the average number of syllables per word (ASW) and the average sentence length (ASL; number of words divided by the number of sentences). The Flesch Reading Ease Score rates text on a 100-point scale; the higher the score, the easier it is to understand the document. For most standard documents, the aim is a score of approximately 60 to 70.
The formula for the Flesch Reading Ease Score is:

$$206.835 - (1.015\ x\ ASL) - (84.6\ x\ ASW)$$

The Flesch-Kincaid Grade Level Score rates text on a U.S. grade-school level. For example, a score of 8.0 means that an eighth grader can understand the document. For most standard documents, the aim is for a score of approximately 7.0 to 8.0.
The formula for the Flesch-Kincaid Grade Level Score is:

$$(0.39\ x\ ASL) + (11.8\ x\ ASW) - 15.59$$

The survey faces the following challenges to these fixed calculations: (a) this is not a "standard document", it is a survey, formatted with repeated introductions, required standardized definitions, and required response formats; (b) the topic of the survey itself ("autonomous" and "transportation") has multiple syllables per word that must be repeated throughout (the word "autonomous" appears 93 times, for example), along with terminology like "paratransit." While all of these multisyllable, higher reading-level words are defined and explained with simpler terminology, the terms themselves remain and are counted towards the overall calculation. See Figures 3-1, 3-2, and 3-3 for, respectively, readability statistics for the entire questionnaire, the questionnaire with repeated introductory text removed, and the questionnaire without repeated introductory text and the word “autonomous” removed.

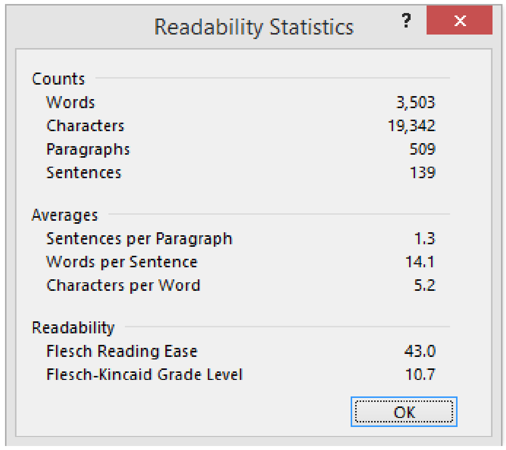

Figure 3-1. Readability statistics for the entire questionnaire

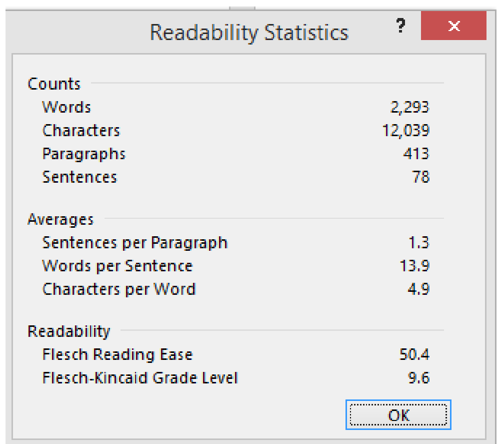

Figure 3-2. Readability statistics with repeated introductory text removed

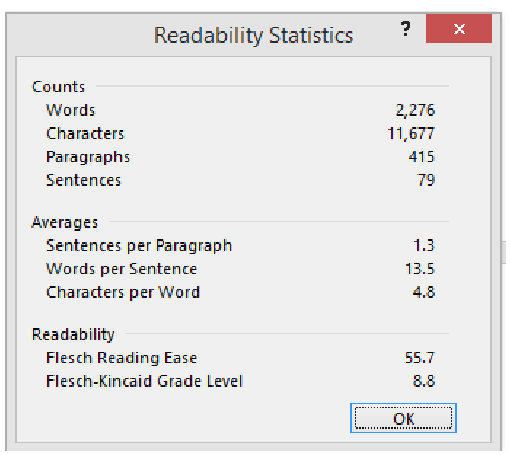

Figure 3-3. Readability statistics without repeated introductory text and “autonomous” removed

After the removal of repeated introductory text and the word “autonomous”, the Flesch-Kincaid Grade Level Score was 8.8, just above the target score of 8, and a reading ease score of 55.7, just below the target score of 60. Given the limitations noted above, and the repeated input of multiple focus groups, we feel confident in the face validity of this survey draft, to be further assessed for content validity by subject-matter experts.

4 ESTABLISH CONTENT VALIDITY OF THE SURVEY

To assess content validity, 10 subject-matter experts were selected with broad but relevant expertise in rehabilitation science, traffic engineering, human factors, gerontology, psychology, transportation planning, and mobility as a service. All 10 subject-matter experts agreed to assess the content validity of the survey. The subject-matter experts were sent CVI rater instructions and the beta version of our survey (i.e., 42 items) without the demographic items, as these items were developed with the SMFLC to align with their previously constructed surveys. The subject-matter experts provided feedback via a Qualtrics survey by rating the relevance of each item on a four-point Likert scale (1 = not relevant, 2 = relevant with major revisions, 3 = relevant with minor revisions, and 4 = very relevant). Furthermore, subject-matter experts provided qualitative feedback to remove, refine, reword, or add survey items to enhance content validity of the survey.

Feedback from subject-matter experts was collated in RStudio (RStudio, Boston, MA, United States) with R version 4.0.2 (R Core Team, 2020), and item-level CVI scores (i.e., the proportion of the ten raters who scored the item as relevant) and scale CVI scores were calculated (Lynn, 1986). Rater scores were collapsed, with an item-level score of 3 or 4 indicating acceptable item relevance and a score of 1 or 2 indicating the need for a major revision or low item-relevance. In the first round of review, 50 of the 52 items were rated above the 80% CVI threshold, whereas 2 of the 52 items had an inadequate CVI (i.e., <80%), suggesting necessary modification of these items. Item-level CVI scores were 100% for 23 items, 90% for 14 items, 80% for 3 items, and 70% for 2 items. Furthermore, two items were generated in response to subject-matter experts' feedback during the first round. This was done to limit double-barreled items and enhance item clarity. Two newly generated items and two modified items with insufficient item-level CVI scores (i.e., 70%) were sent back to the subject-matter experts for a second round of review. After the second round, all four items had adequate CVI (i.e., $\geq$80%). In summary, 54 out of 54 items (100%) were rated above the content validity index cutoff (i.e., $\geq$80%) resulting in a scale content validity index (i.e., average of the mean CVI score for all items) of 95%. The feedback from the subject-matter experts was integrated to refine, reword, and redefine items. This resulted in the refinement (i.e., adding or removing responses, concision) of 15 items and enhanced descriptions of ridesourcing services.

5 ESTABLISH RELIABILITY AND CONSTRUCT VALIDITY OF THE SURVEY

The Qualtrics survey with the user perception survey, henceforth referred to as the FDOT Autonomous RideShare Services Survey (ARSSS) was distributed online using Amazon Mechanical Turk (MTurk). Amazon MTurk provided access to a virtual community of workers from different regions of the country with varying backgrounds, who were willing to complete a human intelligence task (HIT). A HIT was submitted for $5.00 and interested MTurk workers responded using the survey link which directed them to the Qualtrics ARSSS. Participant responses from 553 adults living in the U.S. were used to assess the reliability and construct validity (including the factor structure) as part of determining the final psychometric properties of the ARSSS. MTurk workers were required to be adults ($\geq$ 18 years old) living in the U.S. and have attempted at least 1,000 HITs with a successful completion of at least 95% of their attempted HITs (i.e., Master Workers). One hundred participants were asked to complete the ARSSS again after two weeks. This dataset was used, first, to assess test-retest reliability of the ARSSS. To prevent nesting (i.e., due to similar response patterns from the same participant at different time points), the follow-up responses for this group of 100 participants were not entered into the factor analysis. The final sample of 553 unique participants had demographics ranging in age from 19 years old to 71 years old (M_{Age} = 35.9, SD_{Age} = 10.3). A majority of participants were male (66%) and White (71%). Furthermore, the sample consisted of 19% Asian, 7% Black, and 3% other, ensuring diversity across the sample.

The 54-item ARSSS contained 31 visual analogue scale items, placed on a 100-mm horizontal line with verbal anchors on the extremes, ranging from strongly disagree to strongly agree. Respondents rated their perceptions by moving the slider to correspond with their level of disagreement or agreement. The distance between the marked point and the origin of the line is measured, and then entered as a number, to quantify the magnitude of the response (i.e., ranging from 0 to 100).

Data processing was carried out in RStudio (RStudio, Boston, MA, U.S.) with R version 4.0.4 (R Core Team, 2021), using the psych package in the tidyverse ecosystem. The measurement model was built using an exploratory factor analysis (EFA) among the 31 visual analogue scale items. The other items were not entered into the EFA as they had different response options and thus could not be analyzed using factor analysis techniques. However, item responses that were not selected by any of the 553 respondents, were removed from the survey to enhance concision and limit respondent exhaustion. An EFA was employed to extract the fundamental dimensions of users' perceptions of transportation options. The EFA was built using the principal axis factoring (PAF) method and oblimin rotation. The criterion for loading and cross-loading was set at 0.4, and based on this, items were removed from the subscales. Internal consistency and construct reliability were assessed using Cronbach's alpha and composite reliability, respectively, both at a factor level and scale level.

A sample of 100 MTurk workers was used to estimate the test-retest reliability of the FDOT ARSSS. Participants completed the ARSSS again, two weeks after the first

FDOT ARSSS. The Bland-Altman plot method was used to visually inspect the test-retest reliability after two weeks (see Figure 5-1). Figure 5-1 displays an extreme outlier (i.e., circled in red) with a difference score of 58, after the two-week retest. This outlier was removed and the figure was replotted (Figure 5-2). As displayed in the Figure 5-2, 7 of the 99 within-subject test-retest difference scores were outside of the 95% CI [−16.89, 16.19]. Pearson's *r* and intraclass correlation coefficients (ICC 2,1) were computed to assess the test-retest reliability at the subscale level. A perfect Pearson's correlation of −1 or +1 occurs when the variables are perfectly correlated to one another. ICC reliability values can range from 0 to 1 and can be interpreted as poor (< 0.75), moderate (0.75-0.90), and good (>.90; Fleiss et al., 2013). The total ARSSS scores for test and retest reliability in these 99 participants were significantly and strongly correlated with good reliability ($r = 0.86$, $p < 0.001$, ICC = 0.99). The factor scores for test-retest were also significantly and strongly correlated with good reliability: intention to use, trust, and safety ($r = 0.85$, $p < 0.001$, ICC = 0.99), potential benefits ($r = 0.70$, $p < 0.001$, ICC = 0.97), and accessibility ($r = 0.78$, $p < 0.001$, ICC = 0.96). All individual items for the test and retest reliability correlated significantly, with paired sample correlations ranging from 0.59 to 0.70.

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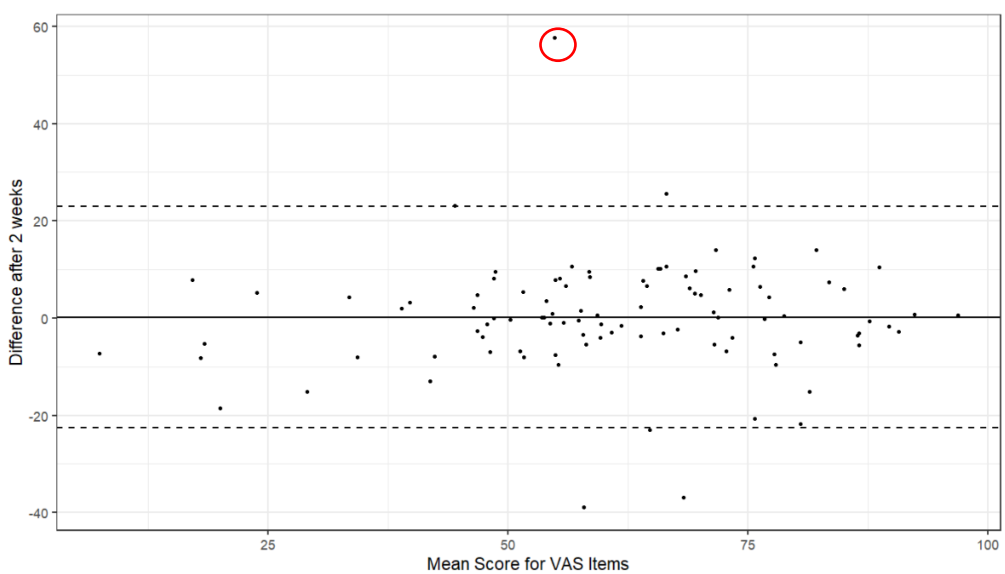


Figure 5-1. Difference between total survey scores after two weeks with an extreme outlier.

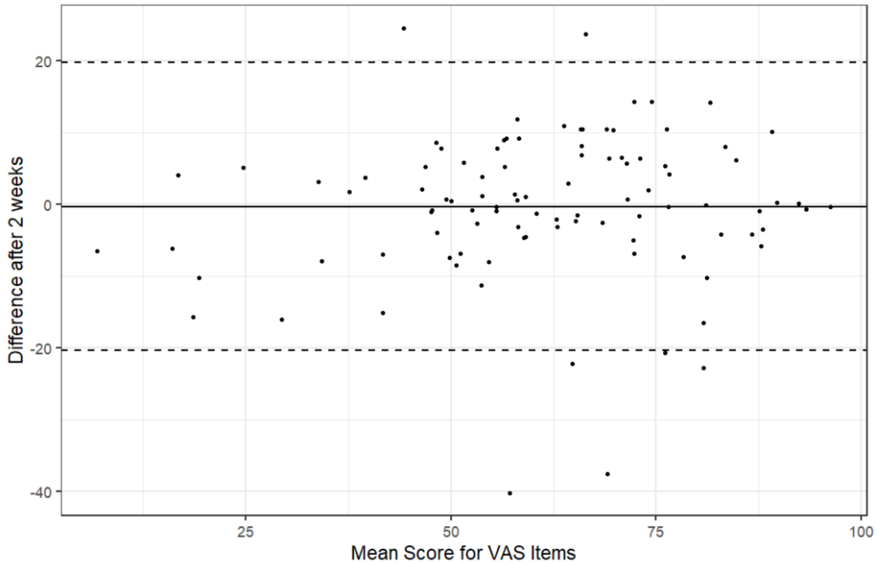


Figure 5-2. Difference between total survey scores after two weeks with the outlier removed.

A normality check was performed for each item by computing the univariate skewness (cutoff score must be $\leq$ 3) and kurtosis (cutoff score must be $\leq$ 10; Kline, 2010). The skew indexes ranged from −0.94 to -0.13; the kurtosis indexes ranged from −0.88 to 1.17. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy suggests that the data seem appropriate for factor analysis: KMO = 0.96. Bartlett's test of sphericity suggested that there is sufficient significant correlation in the data for an EFA: χ^2 (495) = 12,619.65, $p < 0.001$. The Velicer's Minimum Average Partial criterion informed the decision to conduct an exploratory factor analysis with 4 factors.

The results from the initial EFA (see Table 5-1), displayed signs of low-loading items, resulting in 1 item (#33) being removed from the survey. The 4-factor structure with 30 items, explaining 58.65% of the variance, conceptually represented *intention to use, trust, and safety* (13 items), *potential benefits* (7 items), *accessibility* (7 items), and *situation-dependent perceptions* (3 items). The factor labels were determined by assessing item content, commonalities, and Loevinger's coefficient of homogeneity (Fabrigar et al., 1999).

Table 5-1. Item-loading from EFA

Item number	Factor 1	Factor 2	Factor 3	Factor 4
51	.83	-	-	-
39	.68	-	-	-
48	.68	-	-	-
44	.66	-	-	-
45	.65	-	-	-
42	.59	-	-	-
36	.59	-	-	-
30	.58	-	-	-
34	.48	-	-	-
35	.43	-	-	-
41	.42	-	-	-
40	.41	-	-	-
31	.41	-	-	-
23	-	.66	-	-
49	-	.65	-	-
22	-	.64	-	-
50	-	.62	-	-
24	-	.56	-	-
20	-	.53	-	-
21	-	.49	-	-
27	-	-	.81	-
26	-	-	.65	-
29	-	-	.58	-
25	-	-	.58	-
53	-	-	.51	-
28	-	-	.48	-
52	-	-	.45	-
43	-	-	-	.72
46	-	-	-	.49
32	-	-	-	.43
33	-	-	-	-
Variance Explained by each Factor:	23.54%	14.11%	16.05%	4.95%

Note: Maximum values were displayed for item-loading with a cutoff of 0.4.

After the EFA, survey responses of 30 items were assigned to their factor for a confirmatory factor analysis (CFA; see Model 1 in Table 5-1). The situational-dependent factor (Factor 4 in Table 5-1), consisting of 3 items (#32,43, 46), was not significantly related to any of the other three factors, only explained 4.95% of the overall variance, and was removed from the survey. A second CFA was deployed among 27 items, representing 3 factors (see Model 2 in Table 5-2). All fit indices improved after the removal of the 3 items that load on the situational-dependent factor.

Table 5-2. Model parameters and fit indices from the confirmatory factor analysis

	Model Parameters (N = 553)		**Fit indices**		
Models	**Factors**	**Items**	**CFI**	**RMSEA**	**SRMR**
Models 1	4	30	.839	.094	.071
Models 2	3	27	.861	.093	.054

Note: CFI – Comparative Fit Index; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual.

Internal consistency of the ARSSS Cronbach's alpha (cutoff: >0.8) (Cronbach, 1951) and composite reliability (cutoff: >0.7) (Hair et al., 1998) were used to assess the internal consistency of the items and each of its factors. Overall, the internal consistency of this scale was excellent (Cronbach's α = 0.96), with factors ranging from moderate to excellent (range α = 0.89 to 0.94; Table 5-3). The overall Cronbach's α would not be affected by removing any individual items from the scale, as new α's maintained an α of 0.95 with the deletion of any individual item. Similarly, as shown in Table 5-3, the composite reliability measures (i.e., construct reliability) ranged from 0.89 to 0.95.

Table 5-3. Psychometrics and item-loading for each factor

#	**Factor**	**Internal Consistency**	**Composite Reliability**	**Average Variance Extracted**
1	Intention to use, trust, and safety (1)	α = .94	Ω =.95	AVE = .59
2	Potential benefits	α = .90	Ω =.89	AVE = .55
3	Accessibility	α = .89	Ω =.89	AVE = .55
	Situational-dependent perceptions (removed)	α = .56	Ω =.56	AVE = .30

Note: Cronbach's α represents the internal consistency value. McDonald's Ω represents the composite reliability value. AVE – Average Variance Extracted

Lastly, a paper (Appendix A) and online version of our survey was constructed by reorganizing items thematically, to enhance internal consistency reliability (Melnick, 1993). The survey is now organized by the following sections:

- Demographics – Items 1 to 10
- Modes of Transportation – Items 11 – 19
- Perceptions of Transportation Options – Items 20 – 50
  - Factor 1: Intention to Use, Trust and Safety – Items 20 – 32
  - Factor 2: Potential Benefits – Items 35 – 41
  - Factor 3: Accessibility – Items 42 – 48

6 EVALUATE TRAFFIC OPERATIONAL AND DESIGN INTERACTIONS FOR THE AUTOMATED SHUTTLE

6.1 Introduction

6.1.1 Background

Beep (https://www.go-beep.com/), based in Orlando, Florida, provides passenger mobility services including autonomous vehicle shuttles (AVS) that are driverless and electric. Since September 2019, they have been operating several AVS routes in Lake Nona, Florida, a planned community with residential, commercial, recreational, and medical services. The AVS vehicles are built by Navya. Such technologies are relatively new, and it is not clear how the AVS interact with other traffic.

In this task, we evaluated a one-mile-long route located between the Lake Nona Town Center and the Laureate Park Village Center on Tavistock Lakes Boulevard (Figure 6-1). The route is indicated in the figure by the green line and has stops at the Lake Nona Town Center (near Boxi Park), Pixon, and Laureate Park Village Center.

The AVS currently operates with a frequency of 15 min, with the following schedule: Thursday: 6 pm–11 pm, Friday: 6 pm–12 am, Saturday: 10 am–12 am and Sunday: 10 am–10 pm. There is an operator present in every vehicle, so that the drive mode can be switched from automatic to manual. The route includes areas with heavy vehicular, pedestrian, and bicycle traffic.

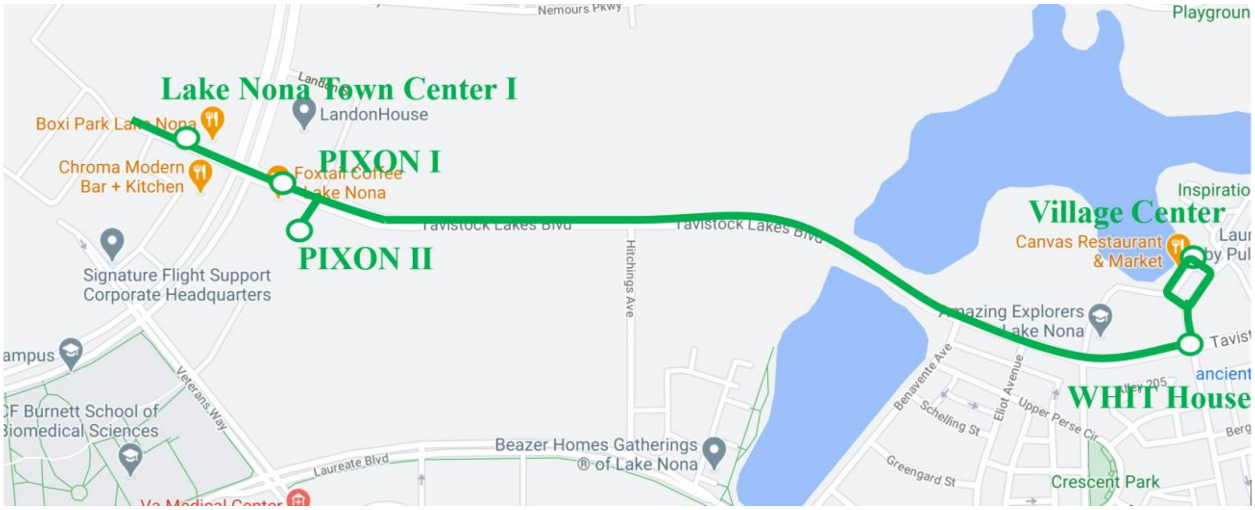


Figure 6-1. Beep AV shuttle route
(Source: https://www.go-beep.com/move-nona)

6.1.2 Objectives

The objective of this task was to evaluate how the AVS at Lake Nona interacts with other vehicles, with pedestrians and bicycles that operate around it, and how the AVS detects and reacts to these other units of traffic. In our research, we observed and categorized behaviors by physical location so that we can relate these to the design characteristics present at that location along the route.

To achieve these objectives, and upon consultation with Beep staff, we selected three locations along the corridor for observing traffic behavior through video data collection (Figure 6-2). These include a crosswalk (Location 1), a signalized intersection (Location 2), and an all-way stop-controlled intersection (Location 3). We collected field data and video observations during the hours of 11:00-13:00 and 14:00-15:00 on Saturday, November 7, 2020, and 15:00-17:00 on Sunday, November 8, 2020.

Videos were recorded using a video camera placed at each of the three locations, and these were used to compare operations without the AVS to operations with the AVS (headways, pedestrian behavior, etc.) Another set of videos was recorded from a dash camera inside a vehicle which followed the AVS as it traveled along its designated route. These videos were used to monitor interactions of the vehicle with other vehicles, other modes, and the infrastructure.

In addition to these videos, we collected data related to the design characteristics along the corridor in order to associate specific behaviors to specific design characteristics. Also, we obtained AVS trajectory data from Beep for the data collection intervals specified above. These data were used to extract acceleration and braking behavior of the AVS while interacting with surrounding traffic.

In the following sections, we discuss operations with and without the AVS at the three observed locations, the results from the dash camera observations, and the results of the trajectory analysis. The last section provides conclusions and recommendations for this task.

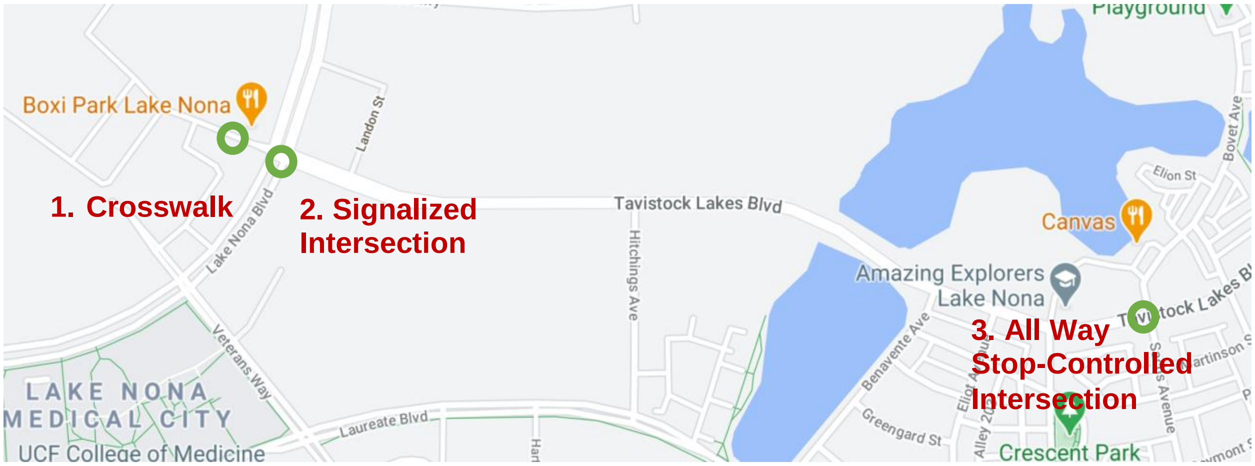


Figure 6-2. Data collection locations

6.2 Crosswalk

6.2.1 Subject crosswalk

The crosswalk in front of Boxi Park (Figure 6-3) near the eastern end of the green line AVS was selected for observation because it is frequently used during weekends. On Saturdays, there is a farmers' market in the area, while on Sundays, the Boxi Park restaurant has live music and attracts many pedestrians. In our observations, we found more pedestrian activity on Saturday than Sunday.

As shown in Figure 6-3, the crosswalk traverses four lanes (one lane in the WB and three lanes in the EB) and is 50 ft. long. During weekends, the EB left turn bay (EB) is blocked using barricades, as shown in Figure 6-4. This creates a refuge island for pedestrians using this crosswalk. The pedestrian volume along this crosswalk is usually highest between 11:00-13:00 on Saturdays due to the presence of the farmers' market. The crosswalk is in close proximity to the signalized intersection to the east (170 ft).

Figure 6-3. Crosswalk site

Figure 6-4. EB left-turn bay blocked using fences

From the videos and other data collected, we observed the vehicular queue with and without the AVS, the discharge headways from the vehicular queue at the crosswalk, and the driver-to-pedestrian yield rate. The details of the data collection and the results for these three performance measures are presented below.

6.2.2 Maximum queue analysis

Using the video collected, the research team obtained the maximum queues at the crosswalk with and without the AVS. For each 15 min period, the researchers recorded the maximum queue that was observed when the queue contained an AVS, and the maximum queue observed when the queue did not contain an AVS. Figure 6-5 shows the maximum queue for each 15-min interval with and without the AVS for Saturday, while Figure 6-6 shows the same information for Sunday. Table 6-1 summarizes the maximum queue data for both days and provides averages by day and by condition. As shown, queues are generally longer on Saturdays, which is likely due to the higher pedestrian volumes during the farmers' market. However, the maximum queue length observations show different trends for Saturday and Sunday:

- On Saturday, when the pedestrian activity is higher and the shuttle frequency is lower, the queues "without AVS" are longer.

- On Sunday, when the pedestrian activity is lower and the shuttle frequency is higher, the queues "with AVS" are longer.

However, a direct comparison of maximum queues with and without the AVS is not fair, because the sample size between the two populations is very different. Generally, within a 15-minute period of observation there were only one or two AVSs in queue, while there were numerous queues observed without an AVS. Also, the vehicular queue lengths depend on the number and extent of pedestrian encounters at the crosswalk. During the project data collection, the AVS passed the crosswalk 22 times in total (7 times on Saturday and 15 times on Sunday). Of these, it encountered pedestrians only 7 times (2 times on Saturday and 5 times on Sunday). However, human drivers encountered pedestrians much more often, and therefore, queues were more likely to be longer when no AVS was present. Therefore, next, we compared queue events with similar queue length with and without an AVS, to assess qualitative differences in the conditions that led to those queues.

We observed that when the vehicle was human-driven, the crossing pedestrians usually communicated with them by gestures or hand signals. This resolved conflicts when pedestrians on the opposing direction's crosswalk were approaching or when they were approaching from the sidewalk to the right of the vehicle and preparing to cross. After gesturing (if they had not started to slow down already), most human-driven vehicles stopped, increasing the yield rate as well as the length of queues "without AVS".

We also observed that when the vehicle was an AVS, pedestrians were generally more attentive. On the two occasions when pedestrian groups with children encountered the AVS, the adult head of the group was highly attentive. On both occasions, the pedestrian group approached from the left of the AVS walking on the opposite direction's crosswalk, and the adult head of the group maintained eye contact with the AVS the entire time.

There were a few occasions when pedestrians were tentative to cross in front of the AVS. They slowed down and let the AVS pass before using the crosswalk. These events are documented in section 6.2.5.

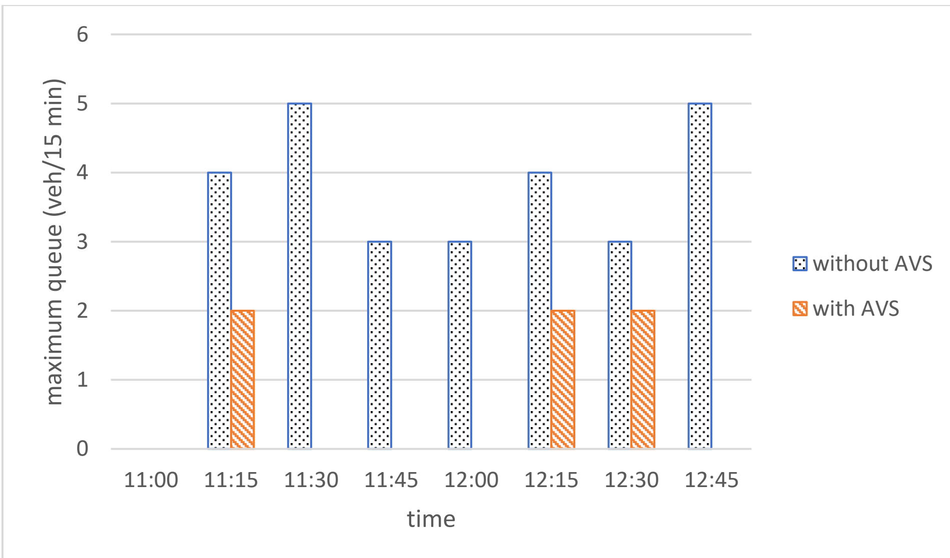


Figure 6-5. Max queue per 15 minutes on Saturday at the crosswalk

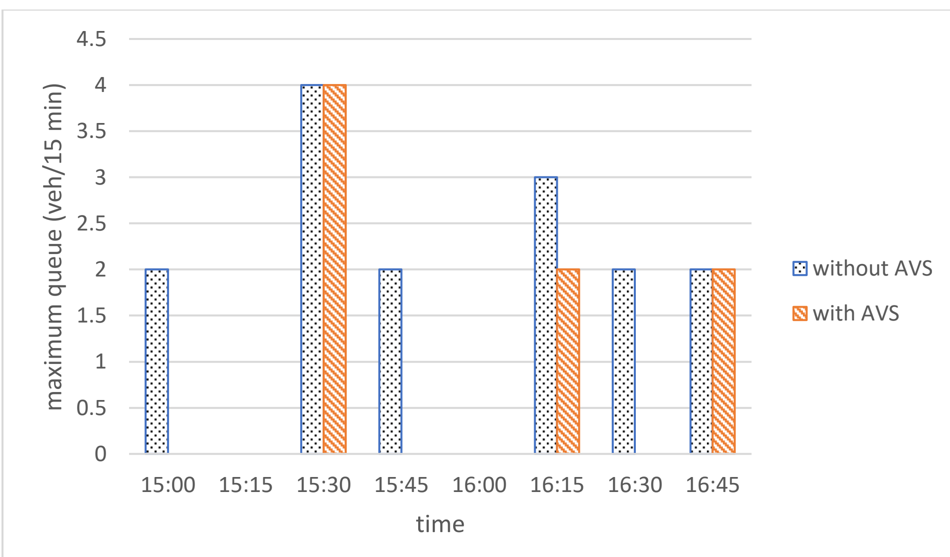


Figure 6-6. Max queue per 15 minutes on Sunday at the crosswalk

Table 6-1. Maximum queue (vehicles) at the crosswalk

	Saturday		Sunday		Average	
	Without AVS	With AVS	Without AVS	With AVS	Without AVS	With AVS
Average	3.4	1.2	1.9	2.7	2.6	1.9
Max	5.0	2.0	4.0	4.0	5.0	4.0
Min	0.0	0.0	0.0	0.0	0.0	0.0
SD	1.5	1.0	1.3	1.5	1.6	1.2

6.2.3 Headway analysis

The average departure headway at the crosswalk was measured during intervals when a queue was formed as vehicles stopped to allow pedestrians to cross. For queues that had at least one AVS, all the headways measured from that particular queue were tagged as “with AVS”. The headways collected when there was no AVS present were tagged as “without AVS”.

Figure 6-7 shows the average headway collected for each 15-min period from 11:00 to 13:00 on Saturday, while Figure 6-8 shows the same information for each 15-min period from 15:00 to 17:00 on Sunday. As shown, the headways with the AVS are generally higher than the headways without the AVS.

Table 6-2 summarizes all data by day and by condition and provides average values. As shown, on average, headways are 2 sec longer with the AVS. This may occur because the AVS accelerates slowly after stopping before the crosswalk. A statistical test was conducted to test whether there was a mean difference between “with AVS” and “without AVS”. The p-value was less than 0.05, which indicates that the two averages are not significantly different.

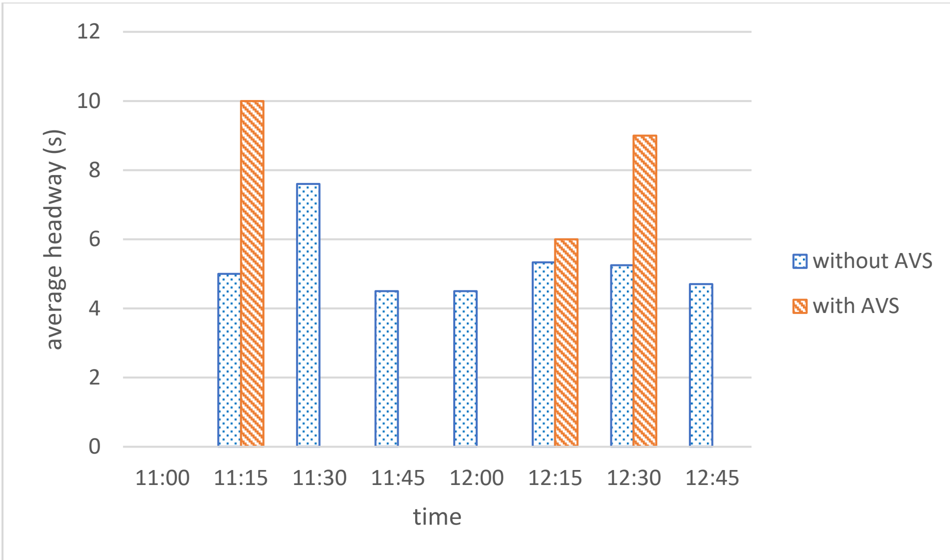


Figure 6-7. Average headway per 15 minutes on Saturday at the crosswalk

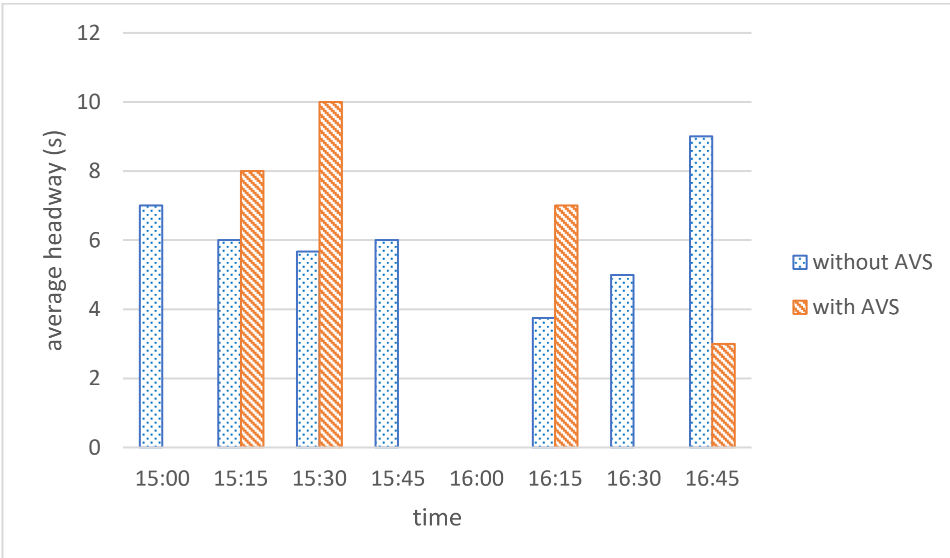


Figure 6-8. Average headway per 15 minutes on Sunday at the crosswalk

Table 6-2. Headway (seconds) at the crosswalk

	Saturday		Sunday		Average	
	Without AVS	**With AVS**	**Without AVS**	**With AVS**	**Without AVS**	**With AVS**
Average	5.3	8.3	6.1	7.0	5.7	7.6
Max	7.6	10.0	9.0	10.0	9.0	10.0
Min	4.5	6.0	3.8	3.0	3.8	3.0
SD	1.3	1.7	1.7	2.4	1.4	2.3

6.2.4 Driver yield rate

The driver yield rate is defined as the ratio of "number of instances of drivers yielding" to the "number of opportunities the drivers had to yield". "Opportunities to yield" are the instances when pedestrians are present and intend to use the crosswalk. In this study, we counted the instances when pedestrians were present in both directions (direction of travel and opposite).The rationale for this is that Florida law (Statute 316.130) states: "the driver of a vehicle at any crosswalk where signage so indicates shall stop and remain stopped to allow a pedestrian to cross a roadway when the pedestrian is in the crosswalk or steps into the crosswalk and is upon the half of the roadway upon which the vehicle is traveling or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger". Figure 6-9 illustrates this statute.

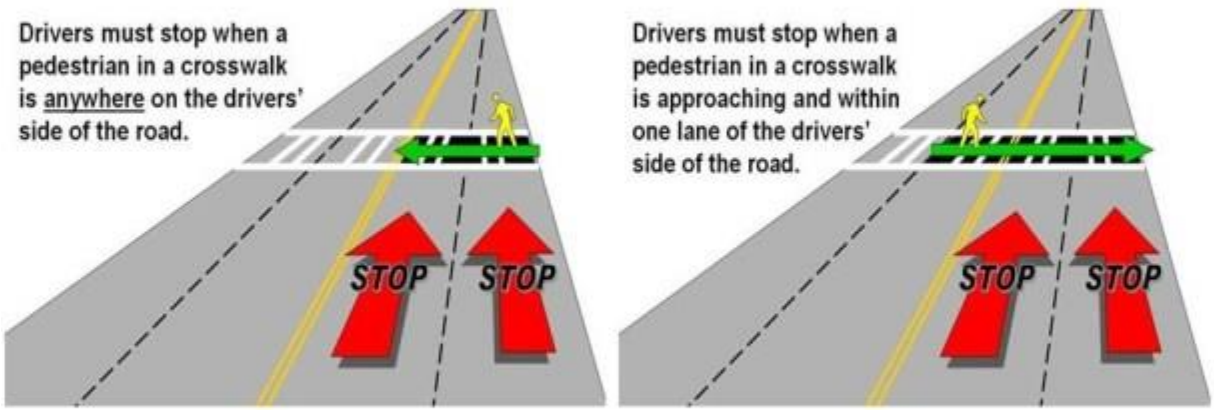


Figure 6-9. Interpretation of Statute 316.130
(Source: https://bikewalkcentralflorida.org/resources/laws/)

Table 6-3 summarizes the data collected for all conditions observed. As shown, the driver yield rate for human-driven vehicles is higher than that observed with the AVS. The reason for this appears to be that the AVS would not recognize or acknowledge the presence of pedestrians when they were on the sidewalk for the opposite direction than that of the AVS. This may be either because the AVS is programmed to consider pedestrians only when they are on the crosswalk in its direction of travel, or because of the presence of the fences shown in Figure 6-4. Table 6-3 summarizes the data for both days and conditions and provides the respective averages.

Table 6-3. Driver yield rate at the crosswalk

	Saturday		Sunday		Average	
	Without AVS	**With AVS**	**Without AVS**	**With AVS**	**Without AVS**	**With AVS**
Opportunities to Yield	58	2	57	5	115	7
Actual Yield	47	1	52	4	99	5
Yield rate	0.81	0.50	0.91	0.80	0.86	0.71

6.2.5 Qualitative observations

In addition to the quantitative analysis discussed above, the research team assembled a list of additional qualitative observations regarding events that occurred during the data collection that are related to the operation of the AVS. These observations are discussed in the following paragraphs.

(1) AVS did not always stop when encountering pedestrians in the crosswalk for the opposing direction

There were a total of five instances when there were pedestrians on the crosswalk for the opposing direction as the AVS was approaching. On two occasions, the AVS stopped and yielded for the pedestrians; however, on three occasions, it did not. In one of the three occasions when the AVS did not stop, there was also a pedestrian on the sidewalk along the AVS's direction of travel who appeared to prepare to cross but slowed down as they approached the crosswalk. Figure 6-10 illustrates one of those events, where the AVS decelerated to a very low speed before the crosswalk, but it kept moving slowly without stopping even though there was a pedestrian (blue circle) in the crosswalk of the opposing direction.

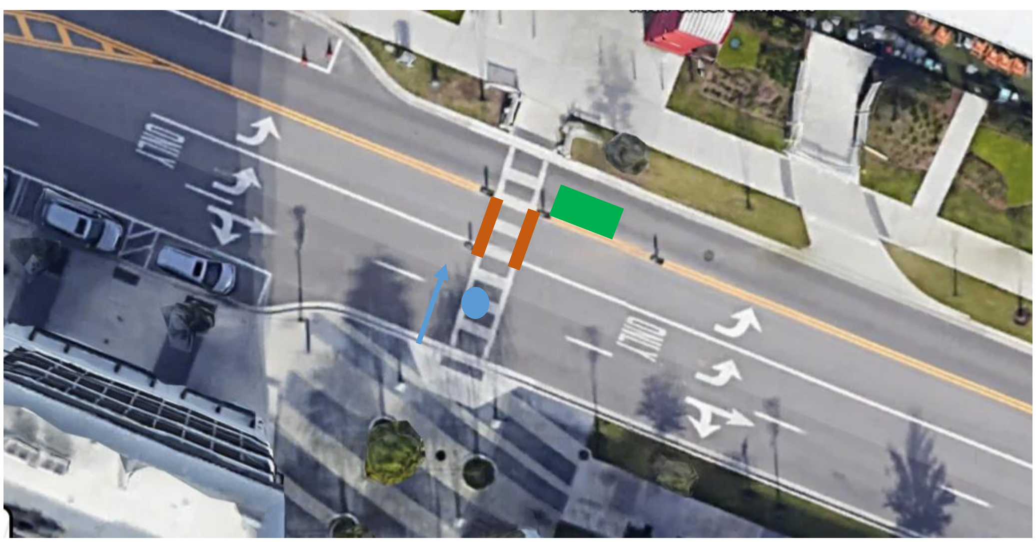


Figure 6-10. AVS did not always stop for pedestrians on the crosswalk for the opposite direction.

(2) AVS encountering pedestrians to the right of the vehicle preparing to cross

There was a total of three instances when the AVS encountered a pedestrian in the sidewalk ahead preparing to cross at the crosswalk. On two occasions, the AVS stopped and yielded for the pedestrians; however, on one occasion it did not. During one of the two occasions when the AVS stopped, the pedestrian was tentative, and they waited until the AVS moved away in order to cross.

On the one occasion when the AVS did not yield, the pedestrian approaching the crosswalk had slowed down their walking speed. It is unclear whether the AVS was able to recognize the slowing pedestrian and made a decision to not stop (Figure 6-11). During this event, there was also another pedestrian in the crosswalk of the opposing direction.

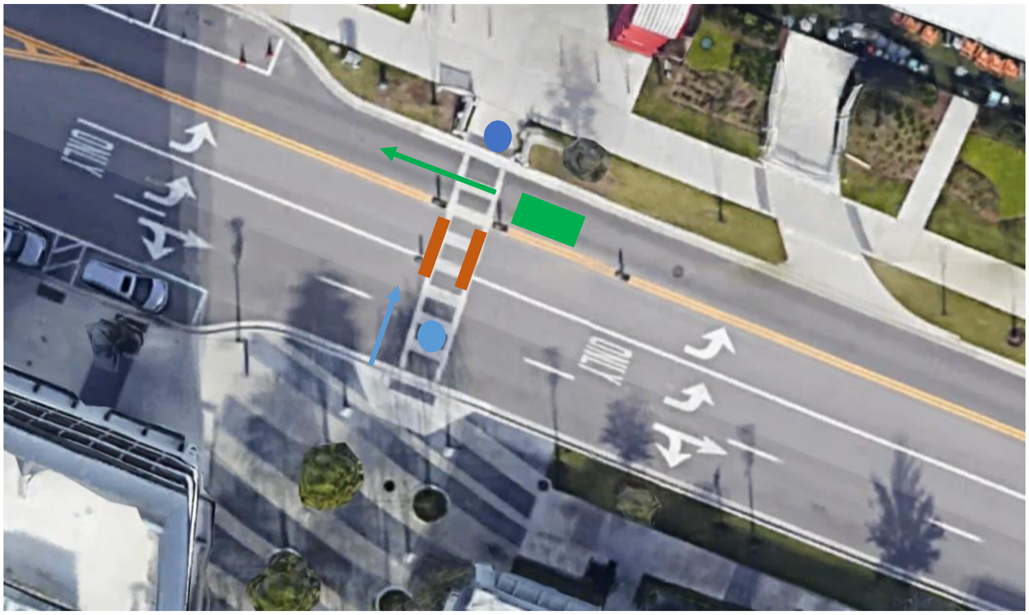


Figure 6-11. AVS did not stop for a slowing pedestrian on the sidewalk and a pedestrian on the crosswalk for the opposing direction.

(3) Pedestrians were tentative about crossing in front of the AVS

On one occasion (Figure 6-12), a pedestrian crossing from south to north was tentative about crossing in front of the AVS. The pedestrian stopped in the middle of the crosswalk when the AVS was more than 50 ft away from the crosswalk. After a moment of hesitation, the pedestrian quickly ran across to the north side just before the AVS arrived at the crosswalk. It appears that pedestrians are used to making eye contact with human drivers who acknowledge their crossing, and in the absence of a driver, they may feel unsafe.

(4) AVS detection

Beep confirmed during a call with UFTI that the LiDAR detection device widens its aperture near the pedestrian crossing to enable detection of pedestrians on the side opposite to the direction of travel. However, the presence of fences in the median causes detection issues.


Figure 6-12. A pedestrian hesitating to cross in front of the AVS

(5) AVS stopping when no pedestrians were present

On two occasions, the eastbound AVS stopped for almost 3 seconds at the crosswalk even though there were no pedestrians present. This only occurred on Sunday in the eastbound direction (Figure 6-13). This may be due to a switch between manual mode and automatic mode as the AVS was in manual mode (as indicated by the electronic message board on the AVS) when it approached the crosswalk and it switched to automatic mode after crossing.

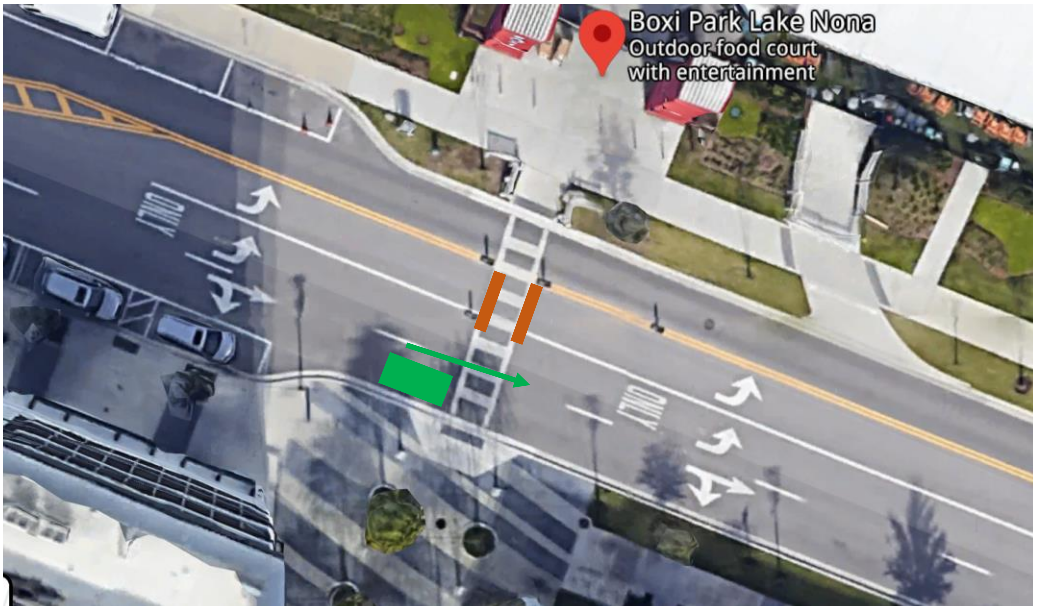


Figure 6-13. AVS stopping when no pedestrians are present

6.2.6 Summary

In summary, the discharge headways at the crosswalk may be slightly longer when the AVS is present, but the difference is not statistically significant. It is not clear whether the AVS is programmed to stop when pedestrians are present in the crosswalk in the opposing direction, or whether its sensors are not able to recognize the presence of pedestrians at that location due to the temporary fences. Also, it appears pedestrians hesitate to cross in front of the AVS, which may be due to the absence of a driver that acknowledges their presence. The driver yield rate for pedestrians was higher without AVS than with AVS.

6.3 Signalized Intersection

6.3.1 Subject intersection

The second location for video data collection was at a 4-leg signalized intersection (Lake Nona Blvd and Tavistock Lakes Blvd). This intersection is located approximately 170 ft to the east of the Boxi Park crosswalk discussed above. The AVS starts from Boxi Park and crosses the signal in the eastbound direction using a shared lane (through and right turn lane). The AVS returns to Boxi Park traveling through the signalized intersection on the westbound middle through lane. To the west of Boxi Park, the Tavistock Lake Boulevard comes to a dead-end. Hence, the vehicular traffic is relatively low in this area.

At this intersection, we used video to observe queue lengths and saturation headways with and without the AVS. Figure 6-14 provides the layout of the intersection. We placed a camera such that it was recording the WB approach, and only when an AVS was in the EB traffic, the camera would be adjusted to capture the AVS arriving from the EB direction. This section discusses the maximum queue analysis, the headway analysis, and qualitative observations at the signalized intersection.

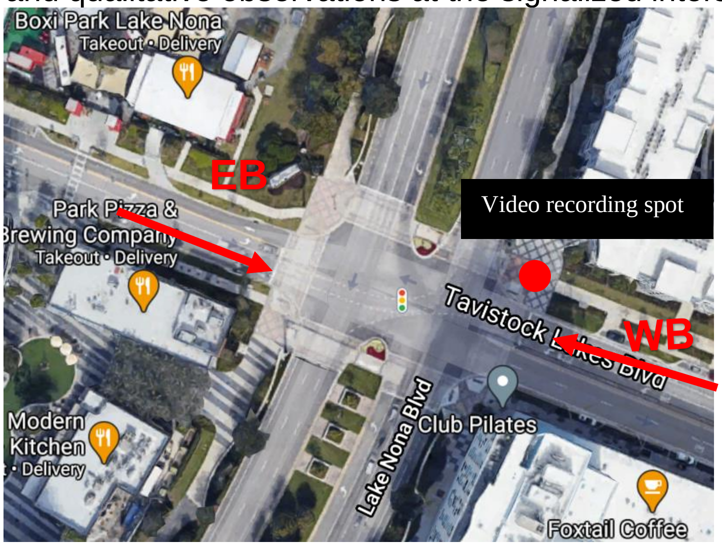


Figure 6-14. Signalized intersection site

6.3.2 Maximum queue analysis

The WB maximum queue “with AVS” and “without AVS” during each 15-min period is provided in Figure 6-15 and Figure 6-16 for Saturday and Sunday, respectively. The max queue along the EB is also given when there was an AVS present. The empty columns indicate that there was no AVS during that 15-min period.

Table 6-4 provides a summary of the data for both days. As shown, the average maximum queue with the AVS is generally somewhat longer (2.3 veh. vs. 1.9 veh). It should be noted that the queues at the signalized intersection are different from the queues at the crosswalk. At the crosswalk, the differences observed in the queue length are highly dependent on the presence or absence of pedestrians. However, at the signalized intersection, the differences in queue length are primarily a function of the AVS presence, given the demand was similar throughout the data collection period. A statistical test was conducted to test whether there was a difference in the average queues between “with AVS” and “without AVS”. The p-value was less than 0.05, which indicates that the queues “with AVS” were significantly longer than those “without AVS”.

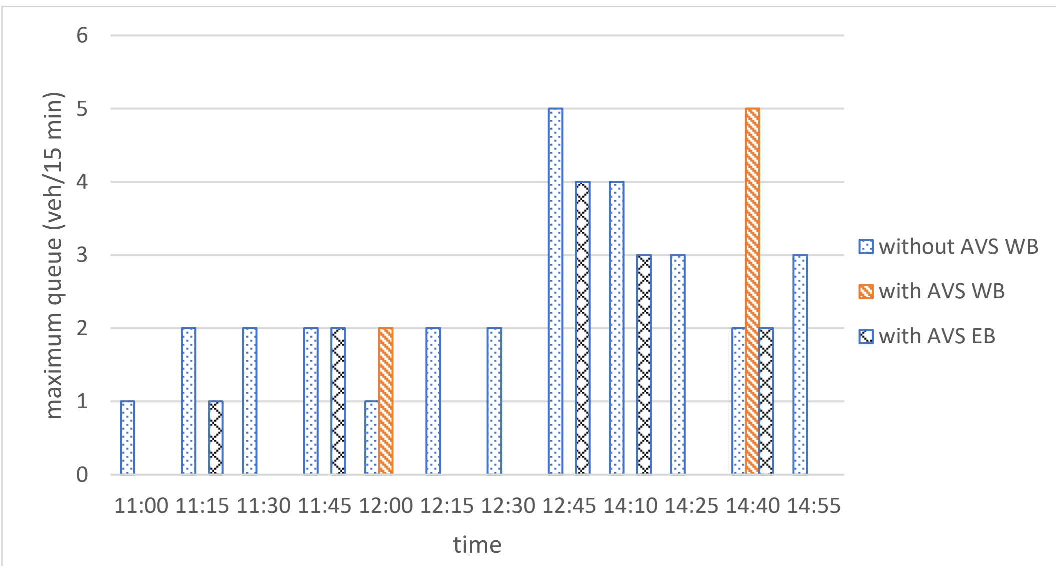


Figure 6-15. Max queue by 15-min interval on Saturday at signalized intersection

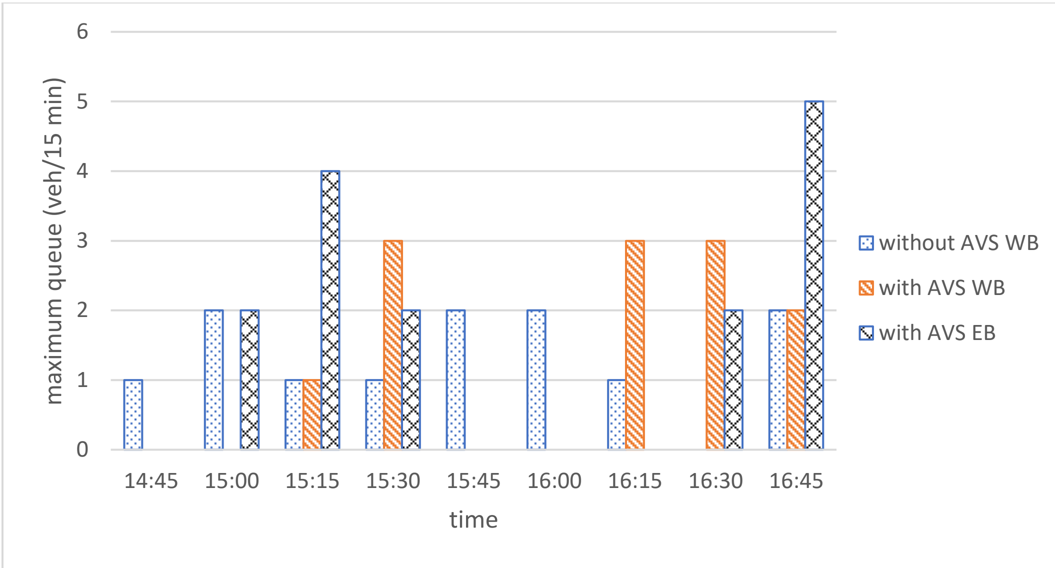


Figure 6-16. Max queue by 15-min interval on Sunday at signalized intersection

Table 6-4. Maximum queue (vehicles) at the signalized intersection

	Average values for Saturday and Sunday		
	Without (WB)	**With (WB)**	**With (EB)**
Average	2	2.3	2.3
Max	5	5	5
Min	0	0	1
SD	1.1	1.6	1.5

6.3.3 Headway analysis

The headway of the first few queue-discharging vehicles at a signalized intersection includes the vehicles' reaction times also known as the "start-up lost time". Hence, the saturation headway (which is used to establish the capacity of the intersection) is measured as the average discharge headway after the effects of start-up lost time have dissipated (usually after the 3rd or 4th vehicle). However, during the data collection, the longest queue length observed was 5 vehicles. Hence, we observed the average headway from the 2nd to the 5th vehicle, and the summary values are presented in Table 6-5. As shown, queues "without AVS" discharge were faster than "with AVS". This could have significant impact on traffic flow for higher traffic demands and/or AVS penetration rates.

Table 6-5. Average discharge headways with and without AVS

	Average Discharge Headway (s)	**Queued Vehicle**			
		2	**3**	**4**	**5**
Average	**Without AVS**	3.7	3.7	2.8	1.7
	With AVS	5.2	3.6	3.7	2.9

6.3.4 Qualitative observations

In addition to the quantitative analysis discussed above, the research team observed an incident where a vehicle that followed the AVS passed the AVS using the left adjacent lane within the intersection after the signal turned green (Figure 6-17). This is likely because the driver of the passing vehicle was impatient with the low speed of the AVS. There was a total of three similar incidents during the data collection, as illustrated in Figure 6-17 (the green rectangle is the AVS, the blue rectangle is the human-driven vehicle).

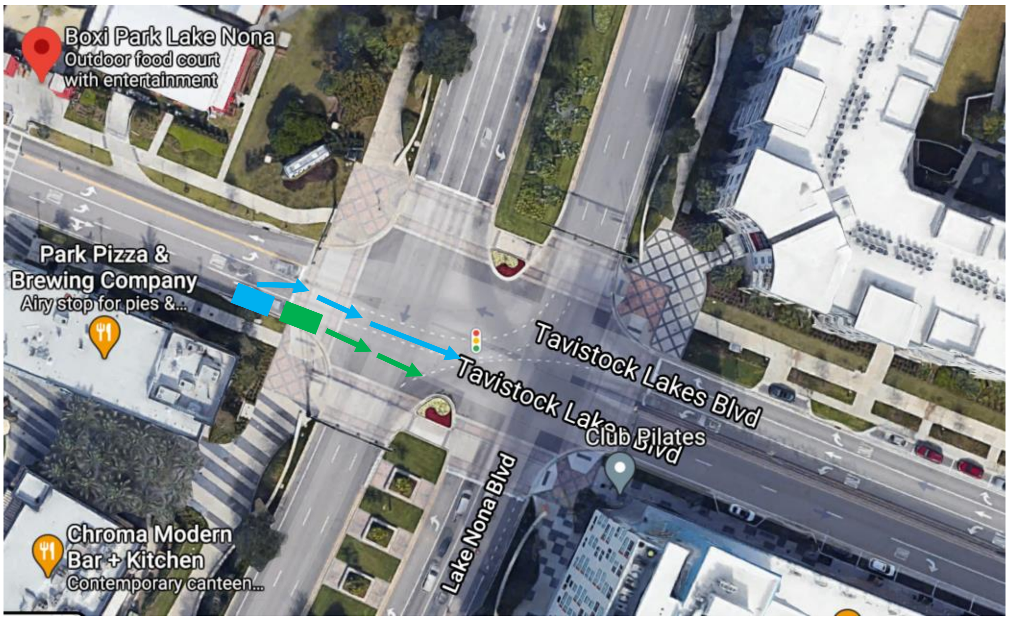


Figure 6-17. Illegal overtaking of the AVS at signalized intersection

6.3.5 Summary

In summary, the discharge headways at the signalized intersection were statistically significantly longer when the AVS was present. There were some unsafe passing incidents of conventional vehicles following the AVS which are likely due to the low speed of the AVS.

6.4 All-Way Stop-controlled Intersection

6.4.1 Subject intersection

The third location where field data were collected is an all-way stop-controlled intersection (Figure 6-18). The AVS approaches from the west and makes a left turn toward Laureate Park (EBL). Because this is an all-way stop-controlled intersection, the vehicles in the queue do not follow the vehicle in front as they wait for their turn. Hence, we observed queuing patterns along the approaches used by the AVS (EB and SB). Field observation indicated that there were no queues forming on the SB approach, and thus, only queues in the EB direction are reported. Very few pedestrians use this intersection; therefore, driver yield rates are not reported for this intersection.

This section discusses the results of the queue analysis and provides qualitative observations for conditions with the AVS at this all-way stop-controlled intersection.

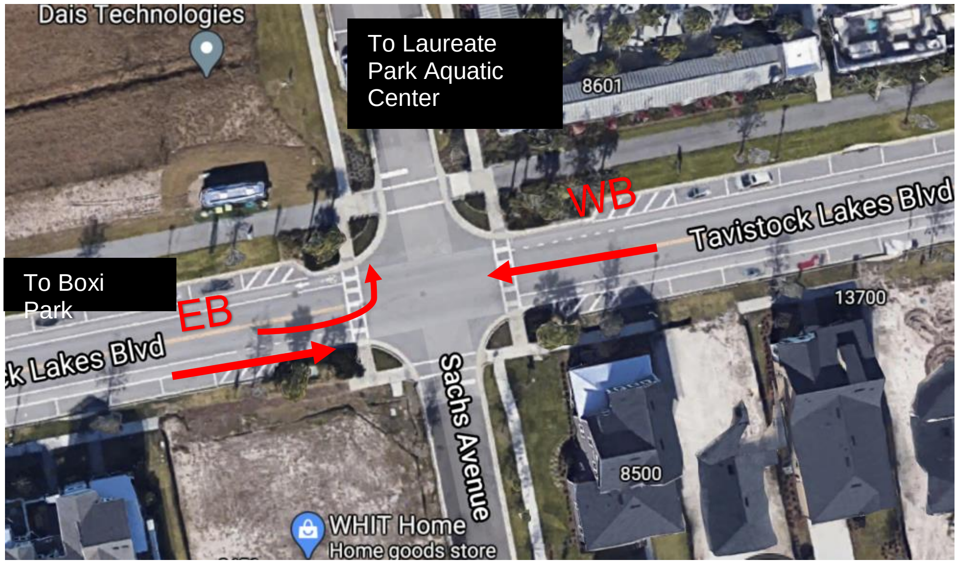


Figure 6-18. All-way stop-controlled intersection site

6.4.2 Maximum queue analysis

The queue length was observed for the EB approach and the maximum queue was observed and recorded every 5 minutes. To be consistent with other observations during this task, the queues are reported at 15 min intervals. Figure 6-19 shows the maximum queue recorded for Saturday, while Figure 6-20 shows the same information for Sunday. As shown, generally the presence of the AVS results in a longer queue (in vehicles) for both days.

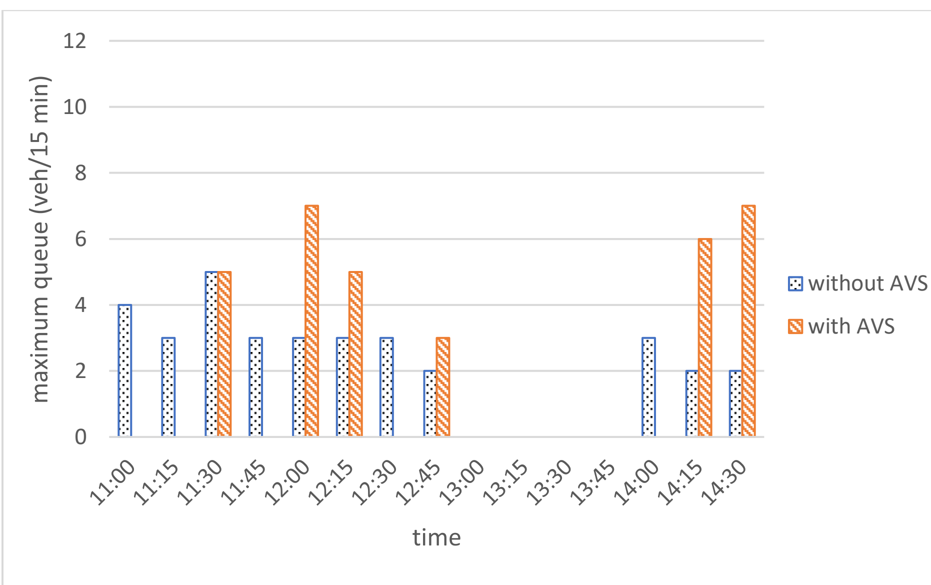


Figure 6-19. Max queue per 15 minutes on Saturday at the all-way stop-controlled intersection

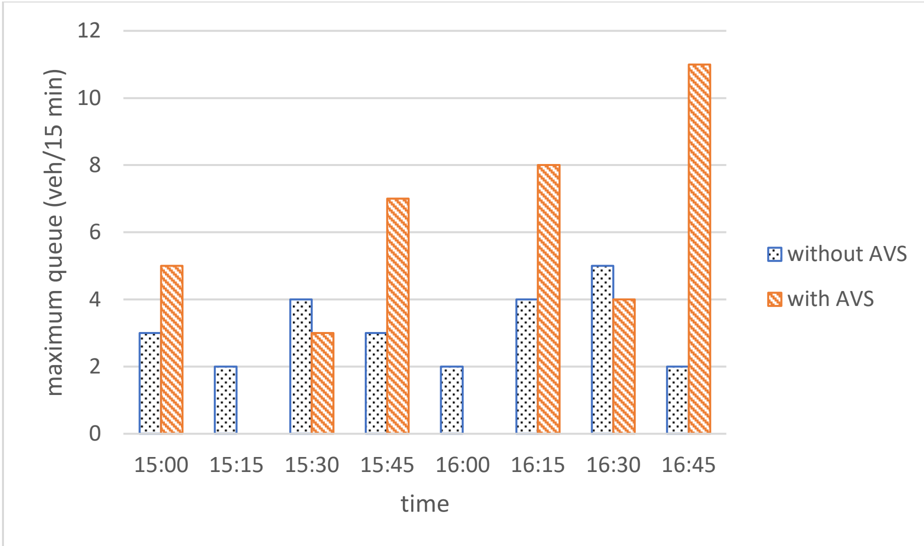


Figure 6-20. Max queue per 15 minutes on Sunday at the all-way stop-controlled intersection

Table 6-6 tabulates the queue lengths by day as well as the average queues by day and condition. As shown, the average queue with AVS is 2.8 vehicles longer than that without it. The p-value is less than 0.05, which means that the queues "with AVS" are significantly longer than queues "without AVS".

Table 6-6. Maximum queue (in vehicles) at the all-way stop-controlled intersection

	Average of Saturday and Sunday	
	Without AVS	**With AVS**
Average	3.1	5.9
Max	5.0	11.0
Min	2.0	3.0
SD	0.9	2.2

6.4.3 Qualitative observations

In addition to the quantitative analysis discussed above, the research team assembled a list of additional qualitative observations which are discussed in the following paragraphs.

(1) Opposing-through conventional vehicle failing to yield to the AVS

During the data collection, an opposing-through conventional (WBT) vehicle at the intersection failed to yield to the AVS as it was traveling eastbound, when it was the AVS's turn to move. This case is illustrated in Figure 6-21, where the green rectangle represents the AVS and the blue rectangle represents the opposing-through conventional vehicle. All approaches had vehicles queued, and the AVS had the right-of-way.

The AVS proceeded safely into the intersection to make a left turn, but a vehicle from the opposing direction went through the intersection, and the AVS was forced to slow down (and abort the left turn) to avoid a collision. The AVS was moving slowly on automatic mode when approaching the stop bar, and it fully stopped at 11:40:30 am. Then it began to move with a very low acceleration and passed the stop bar at 11:40:38 am. When the AVS was in the intersection box, an opposing vehicle was approaching at high speed. At that time, the operator maneuvered the AVS for 8 s in manual mode. After the operator completed the left turn, the AVS was returned to autonomous mode. It is possible that the driver missed the all-way stop sign or thought the AVS was intending to yield, given its low speed.

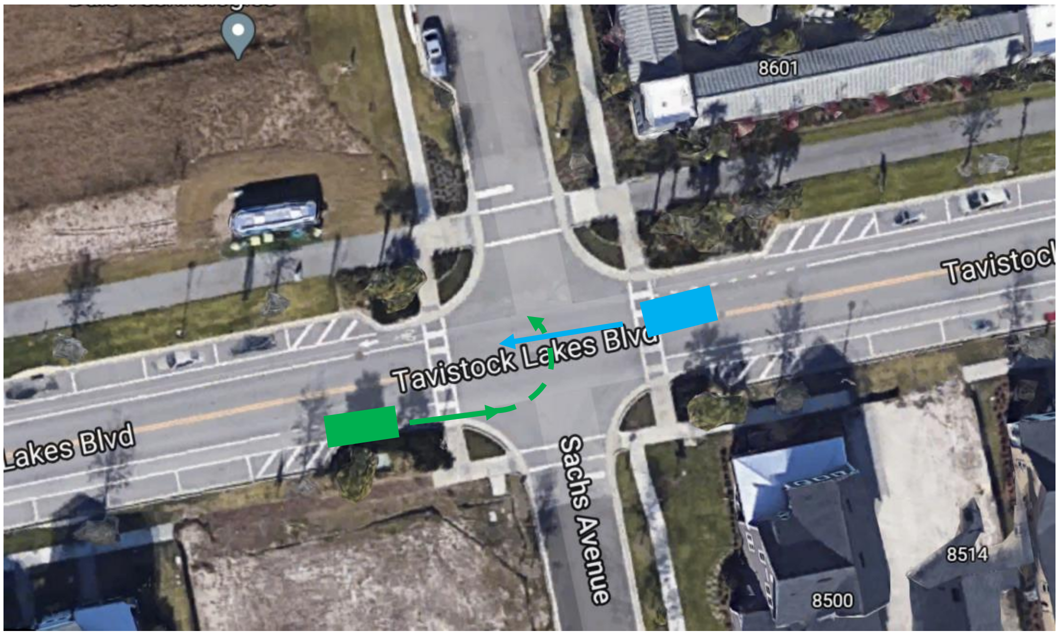


Figure 6-21. Conflict of the left-turning AVS with opposing-through vehicle

(2) Illegal overtaking of the AVS

In one instance, there were two vehicles following the AVS, and both overtook the AVS using the lane in the opposite direction, even though passing is prohibited at that location and there is a double yellow line separating the two directions. There were no vehicles in the opposing lane, and this road segment has generally good visibility. It appears drivers may get frustrated with the AVS's slow speed when there are no opportunities for passing.

6.4.4 Summary

In summary, the average queue length for the left-turn lane, which is used by the AVS, is longer when the AVS is present. Also, the low speed of the AVS seems to create frustration, as illustrated by illegal passing.

A note on bicyclists – There were no bicyclists observed near the Boxi Park area (west end of the corridor). At other sections, we did observe bicyclists. Although there is a bicycle lane on Tavistock Lakes Blvd, the bicyclists we observed used the pedestrian pathway (separated from vehicular traffic). Except for the Boxi Park area (west end of the corridor), pedestrians were sparsely found in other sections. This might be one of the reasons bicyclists preferred to use the pedestrian pathway. Due to this, we were not able to record any instances of the AVS interacting with bicyclists.

6.5 Dash Camera Data

The dash camera data were collected by a human-driven vehicle following the AVS along the green line shown on Figure 6-22 on Saturday, November 7, 2020. Using this recording, we identified several notable events, which are described in this section.

From the video data, there were several important incidents. In the following figures, the green rectangle is the shuttle, and the blue rectangle is the human-driven vehicle.

Figure 6-22 illustrates that the AVS always stops at a curb opening halfway through the trip to allow the following vehicles to pass because the AVS operates at speeds much lower than the speed limit. This appears to be a good solution for operating an AVS when its speed is much lower than the speed limit (25 mph).

Beep confirmed during a call with UFTI that the speed of the AVS is a constraint of the automation, and they recommend such stops with AVS every 0.5 mile when there is only one lane in the direction of travel. Beep also noted that they are using different vehicle models such as “Olli” in their other deployments, which operate at higher speeds.

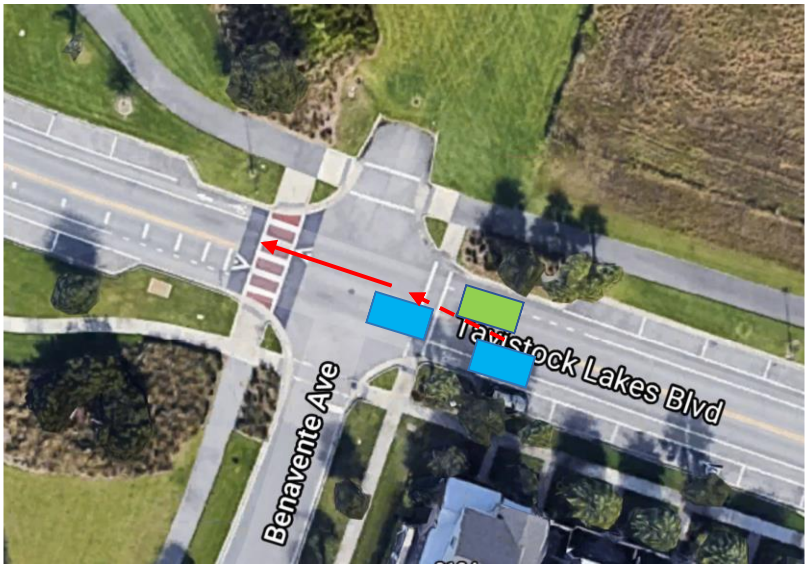


Figure 6-22. AVS moves off the road to allow passing

As indicated earlier, the AVS was overtaken by two conventional vehicles using the opposite lane, illegally violating the double yellow line (Figure 6-23). This event was recorded both by the dash camera and by the video camera at the all-way stop-controlled intersection.

Figure 6-23. Human-driven vehicle overtakes AVS illegally

In another instance, the AVS was overtaken by a conventional vehicle using the parking spaces, which is an illegal maneuver (Figure 6-24).

Figure 6-24. Human-driven vehicle overtakes AVS using parking spaces

6.6 Trajectory Data Analysis

Trajectory data for the AVS were provided by Beep. These data include time (yyyy-mm-dd hh:mm:ss), vehicle ID, battery level (percentage), driving mode (manual or automatic), speed (mph), acceleration (m/s^2), location_lat (latitude), location_lon (longitude), and heading (degrees). Figure 6-25 is a snapshot of these trajectory data. The next subsections discuss driving mode conditions (automated vs. manual), speeds, overall acceleration and deceleration information, and acceleration and deceleration by location along the route.

	time	vehicle	batterCharge	drivingMode	speed	acceleration	location_lat	location_lon	heading
0	2020-11-07 11:00:00.826	VG9A2CB2CJV019127	0.87	manual	0.0	0.319395	28.370947	-81.261215	37.050102
1	2020-11-07 11:00:01.827	VG9A2CB2CJV019127	0.87	manual	0.0	0.319395	28.370947	-81.261215	37.053604
2	2020-11-07 11:00:02.827	VG9A2CB2CJV019127	0.87	manual	0.0	0.321141	28.370947	-81.261215	37.071915
3	2020-11-07 11:00:03.829	VG9A2CB2CJV019127	0.87	manual	0.0	0.322886	28.370947	-81.261215	37.084057
4	2020-11-07 11:00:04.826	VG9A2CB2CJV019127	0.87	manual	0.0	0.322886	28.370947	-81.261215	37.083004

Figure 6-25. Data sample showcase

6.6.1 Driving mode analysis

Since the AVS is still in pilot testing, there is an operator in every vehicle to ensure the safety of passengers and to address unforeseen events. Also, the operator takes over during certain portions of the route. When the operator is controlling the AVS, it is in “manual mode”, and when the autonomous logic is operating the vehicle, it is in “automatic mode”. Figure 6-26 illustrates the portions of the route operated under manual mode and automatic mode. Figure 6-27 shows the number of seconds the AVS operated under each of the two modes for the data set we analyzed. Overall, the AVS operates on automatic mode for 58% of the time.

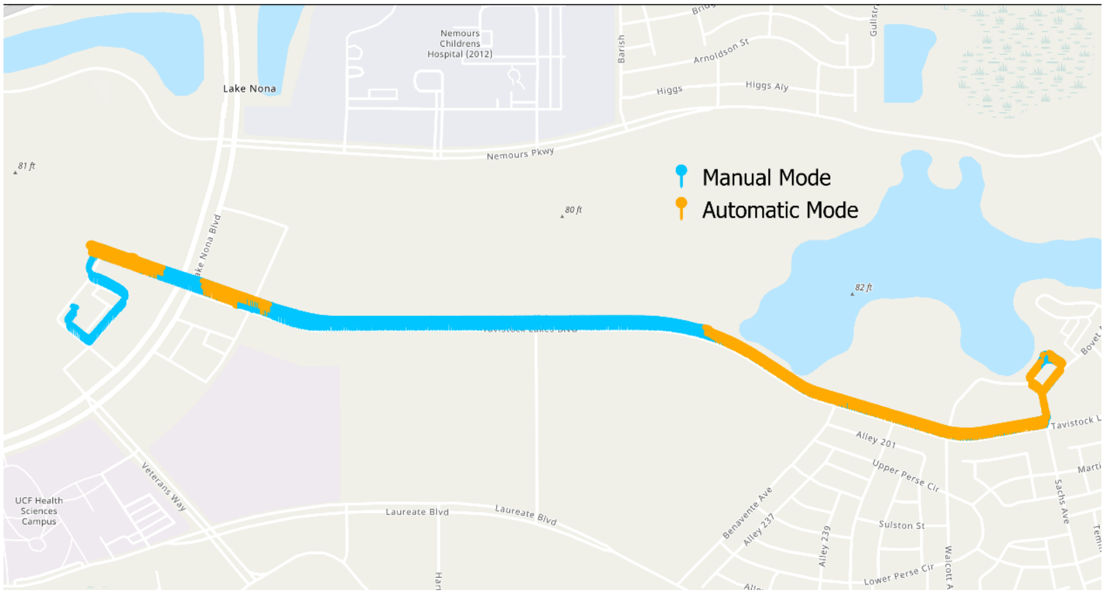


Figure 6-26. Trajectories of manual mode and automatic mode

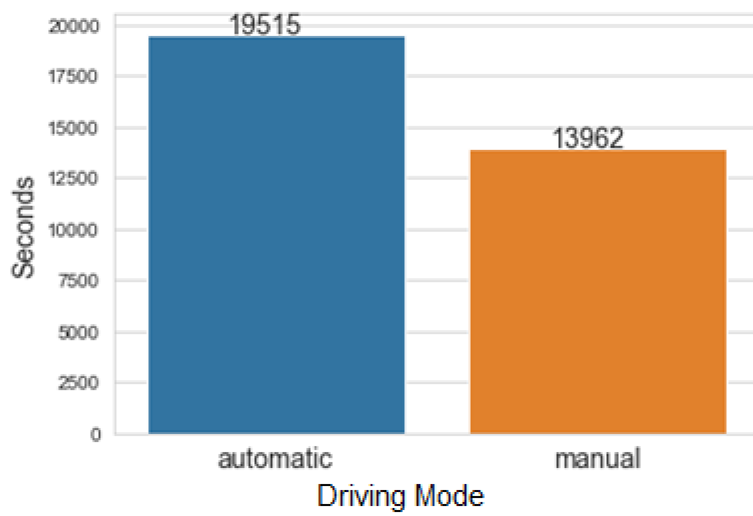


Figure 6-27. Driving mode

6.6.2 Manual mode analysis

Based on the trajectory data obtained by Beep, the AVS operates in manual mode along the middle section of the Tavistock Lake Blvd. At the time of data collection, lane markings along this section were recently changed. This could be a reason the AVS was operating in manual mode along this stretch of the road.

During manual mode, the speed ranged from 0–11.67 mph. During approximately 75% of the time (manual mode), the speed of the AVS ranged between 0 ~ 8.0 mph. For 62.6% of the time, the CAV remained idle, while the second most frequently observed speed during the manual mode was 11 mph (22.0%). Figure 6-28 and Figure 6-29 provide a boxplot and histogram of the AVS speeds, respectively.

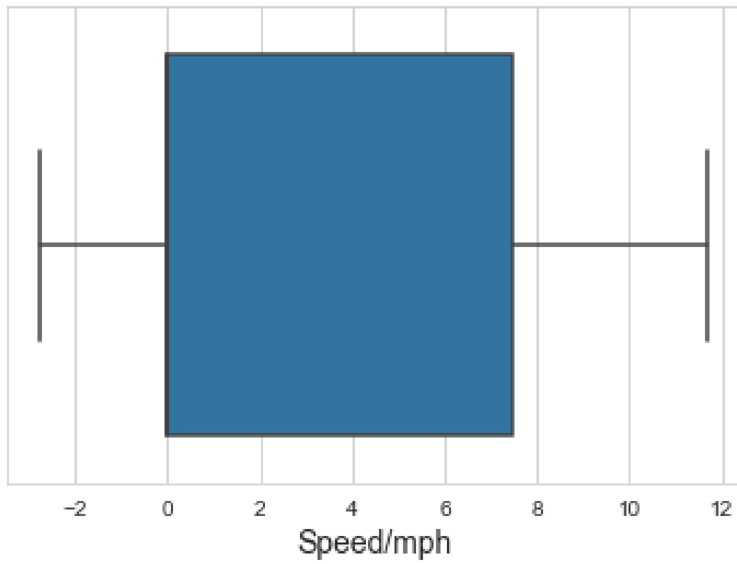


Figure 6-28. Manual mode speed boxplot

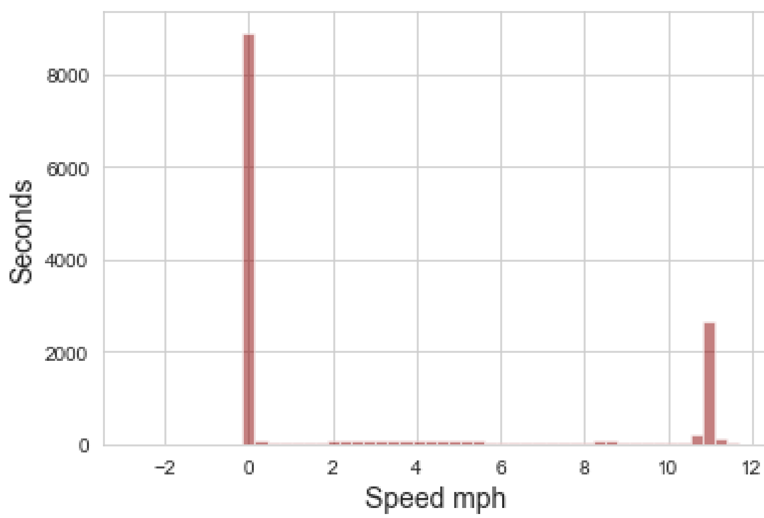


Figure 6-29. Manual mode speed histogram

6.6.3 Automatic mode analysis

The AVS operated in automatic mode along most of the road except for the middle section (where the lane markings were recently changed) and near the signalized intersection. During automatic mode, the speed ranged from −0.87 mph (the speed is negative when the vehicle is reversing) to 11.88 mph, and 75% of the time, the speed ranged from 0 to 4.3 mph. For 62.4% of the time, the CAV remained idle (Figure 6-30, Figure 6-31).

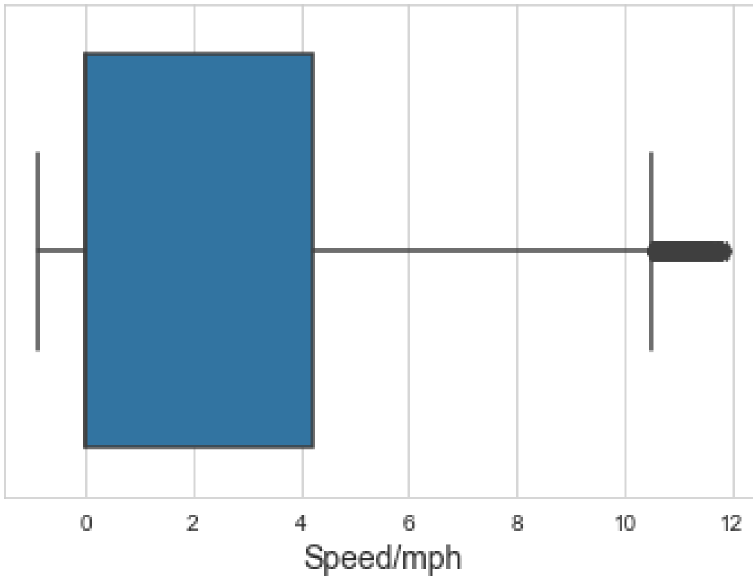


Figure 6-30. Automatic speed boxplot

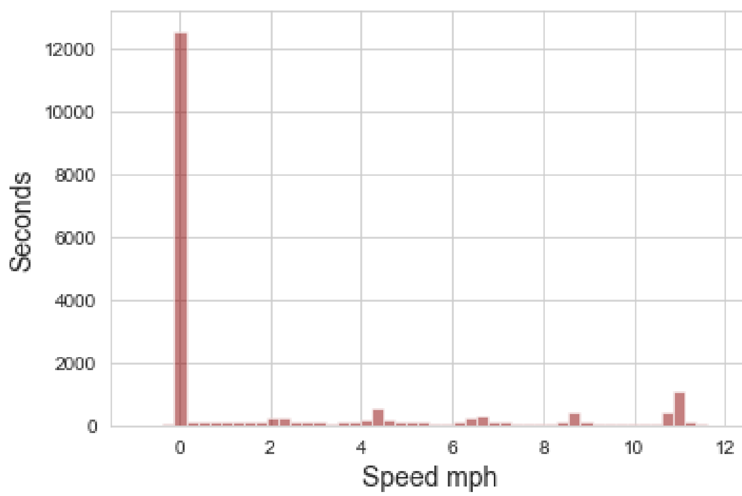


Figure 6-31. Automatic speed histogram

6.6.4 Speed analysis

The speed ranged from −2.74 mph (speeds are negative when the AVS is reversing) to 11.88 mph. Most frequent speeds were from 0 to 5 mph. For 62.5% of the time, the CAV stayed idle (Figure 6-32, Figure 6-33).

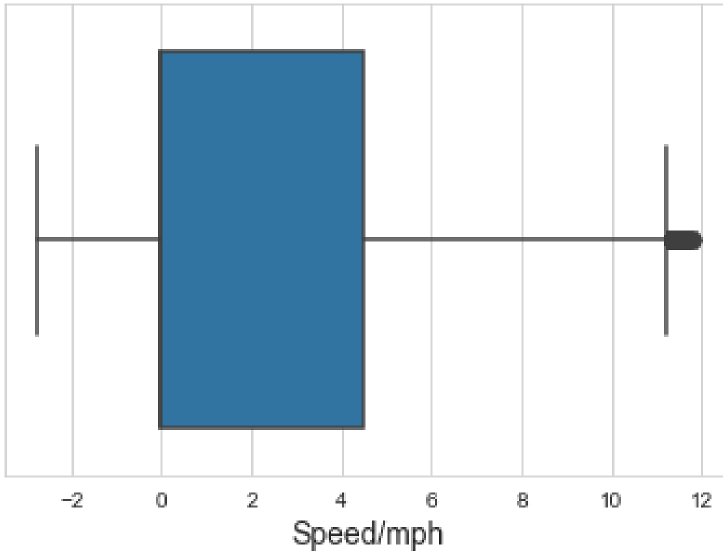


Figure 6-32. Speed boxplot

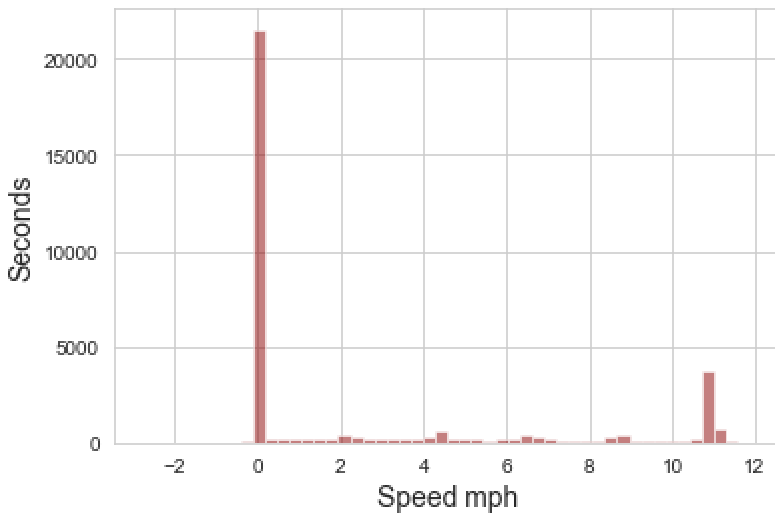


Figure 6-33. Speed histogram

By analyzing the idling speed distribution (Figure 6-34), we determined that most idling speed locations were near shuttle stop sites. During idle times, the AVS was typically located at a bus stop. Sometimes the AVS waited for about 30 minutes at the Lake Nona Town Center stop; hence, the proportion of stopped times was relatively high.

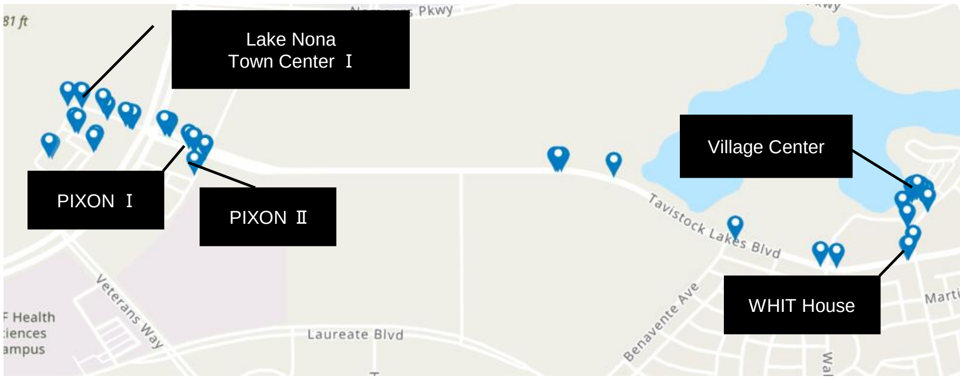


Figure 6-34. Idling speed distribution

6.6.5 Acceleration analysis

Figure 6-35, Figure 6-36, and Figure 6-37 provide the acceleration of the AVS. From these data, we can conclude the following:

- The maximum acceleration recorded during the data collection was 6.59 m/s^2. The proportion of uncomfortable acceleration (>0.9 m/s^2) was 5.4% (Bae et al., 2019);
- The maximum deceleration recorded during the data collection was −1.72 m/s^2. The proportion of uncomfortable deceleration (<−0.9 m/s^2) was 0.2%;
- Most of the time, the acceleration ranged from 0 m/s^2 ~ 0.26 m/s^2. The proportion of uncomfortable acceleration and deceleration was 5.6%
- The uncomfortable acceleration/deceleration (acceleration > 0.9 m/s^2, or deceleration < −0.9 m/s^2) occurs more frequently during automatic mode (58.23%) than manual mode (41.77%). However, this was likely because, overall, the AVS was more frequently in automatic mode. When examining these proportionally, the percentage of uncomfortable acceleration/deceleration points for automatic mode (5.62%) was similar to that of the manual mode (5.63%).

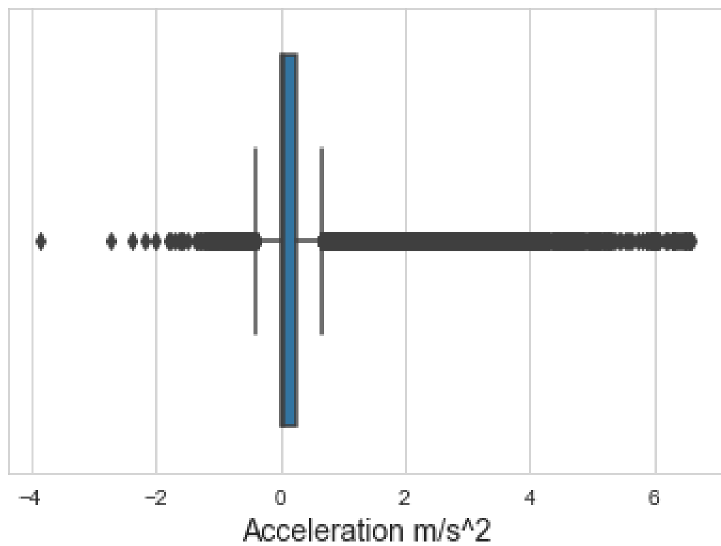


Figure 6-35. Acceleration boxplot

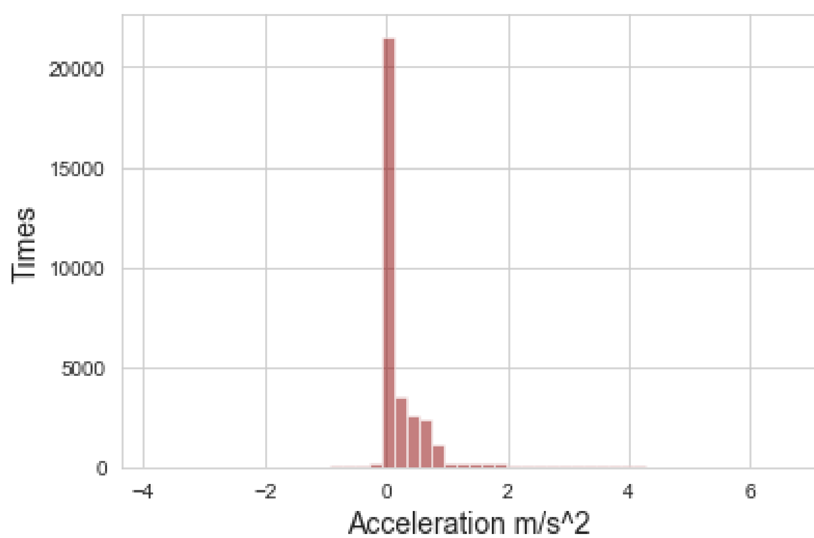


Figure 6-36. Acceleration histogram

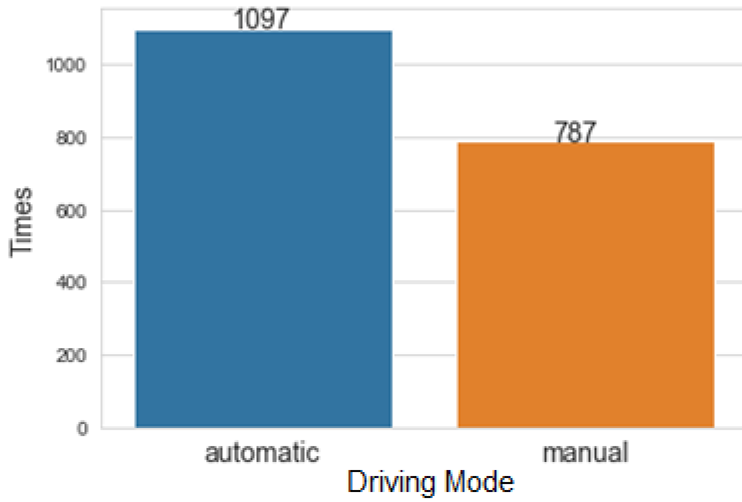
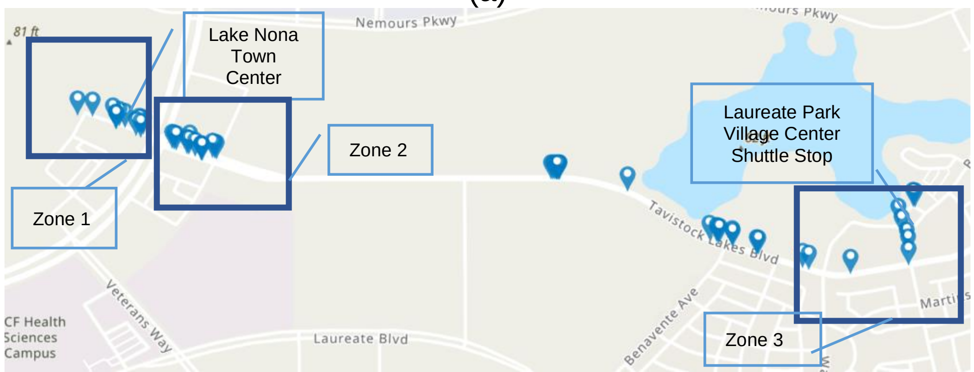


Figure 6-37. Driving mode counts with uncomfortable acceleration/deceleration

6.6.6 Locations of high acceleration and high deceleration observations

There are three locations where uncomfortable accelerations and decelerations were recorded, and these are shown in Figure 6-38. These three zones are around the three data collection sites discussed above: crosswalk, signalized intersection, and all-way stop-controlled intersection.

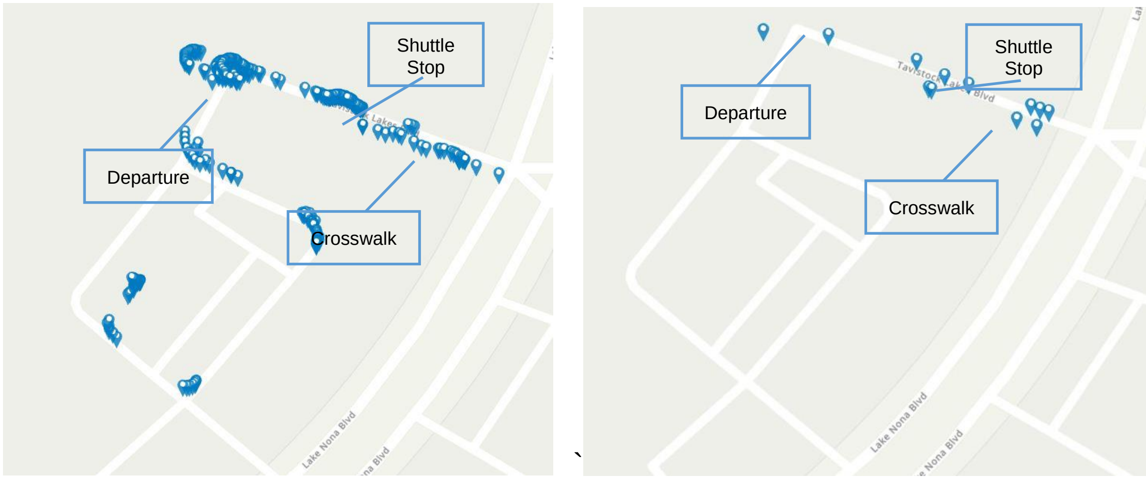
(a)



(b)

Figure 6-38. Uncomfortable acceleration/deceleration positions: (a) acceleration, (b) deceleration

Figure 6-39 provides the detailed acceleration and deceleration data for the sidewalk location, which has a high density of uncomfortable accelerations and decelerations. This is a high-pedestrian traffic area, and it is likely that the presence of pedestrians led to frequent abrupt accelerations and decelerations. As shown in Figure 6-39, the uncomfortable accelerations (Figure 6-39a) occurred more frequently than decelerations (Figure 6-39). This is somewhat unexpected because it seems the cause of potential discomfort is not as much the presence of pedestrians and sudden stops but mostly the programming of the AVS.



(a) (b)

Figure 6-39. Uncomfortable acceleration/deceleration locations near the crosswalk

As shown in Figure 6-40, according to the trajectory information supplied by Beep, there were very few uncomfortable acceleration and deceleration events around the signalized intersection. However, there were numerous uncomfortable acceleration events observed near the all-way stop-controlled intersection (Tavistock Lakes Blvd at Landon Street). It seems that uncomfortable accelerations are highly related to shuttle stop sites, but decelerations are not.

(a) (b)

Figure 6-40. Uncomfortable acceleration/deceleration positions near the signalized intersection (Zone 2)

Figure 6-41 shows the uncomfortable acceleration positions around the all-way stop-controlled intersection. Compared with the signalized intersection, the AVS was observed to have many more uncomfortable acceleration events at the all-way stop-controlled intersection, where all vehicles must always stop.

(a) (b)

Figure 6-41. Uncomfortable acceleration/deceleration positions near the all-way stop controlled intersection (Zone 3)

6.7 Conclusions

In this task, the research team evaluated how the AVS at Lake Nona interacted with other vehicles, with pedestrians and bicycles that operate around it, and how the AVS detected and reacted to these other units of traffic. We selected three locations along the AVS route for observing traffic behavior through video data collection: a crosswalk, a signalized intersection, and an all-way stop-controlled intersection. We collected field data and video observations during the hours of 11:00-13:00 and 14:00-15:00 on Saturday, November 7, 2020, and 15:00-17:00 on Sunday, November 8, 2020.

Regarding the pedestrian crosswalk, we concluded that the discharge headways at the crosswalk may be slightly longer when the AVS is present, but the difference was not statistically significant. It is not clear whether the AVS is programmed to stop when pedestrians are present in the crosswalk in the opposing direction or whether its sensors are not able to recognize the presence of pedestrians at that location due to the temporary fences. Also, it appears pedestrians hesitate to cross in front of the AVS, which may be due to the absence of a driver that acknowledges their presence. The driver yield rate for pedestrians was higher without AVS than with AVS.

Regarding the signalized intersection, we concluded that the discharge headways are statistically significantly longer when the AVS was present. There were some unsafe passing incidents of conventional vehicles following the AVS which were likely due to the low speed of the AVS.

Regarding the all-way stop-controlled intersection, the average queue length for the left-turn lane, which was used by the AVS, was longer when the AVS was present. Also, the low speed of the AVS seems to create frustration, as illustrated by illegal passing.

From the analysis of the trajectory data, we determined that most of the manual mode speed was from 0 ~ 8.0 mph while most of the automatic mode speed was 0 ~

4.3 mph. The automatic mode caused more uncomfortable accelerations than the manual mode. We found that most of the uncomfortable accelerations and decelerations occurred around the crosswalk and the stop sites.

Overall, the AVS may result in lower throughputs and lower speeds, and its low operating speed may contribute to an increase in illegal passing.

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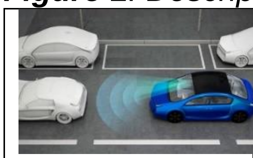
APPENDIX A FDOT AUTONOMOUS RIDEHSARE SERVICES SURVEY

Welcome to the University of Florida & Florida Department of Transportation Autonomous RideShare Services Survey (ARSSS). We are interested in better understanding your experiences with and thoughts on autonomous vehicles, ridesourcing services, and ridesharing services.

As you complete this survey, please refer to this figure and note the following definitions:

***Figure 1**. Description of Transportation Services*

				
Autonomous Vehicles Personally owned vehicles capable of observing the surroundings and driving, in certain situations, without human input.	***Autonomous taxis*** Self-driving vehicles operated by a commercial company for personal use.	***Autonomous Shuttles*** Self-driving vehicles operated by a commercial company with a capacity of 12 passengers.	***Ridesourcing services*** Services that use smartphone apps to connect passengers with drivers who use their own car. For example, Uber, Lyft, or other ridehailing services.	***Ridesharing services*** For example, traditional carpools or ***sharing*** a ride with other users through ridesourcing services.

Note: *You may tear this sheet from your survey packet.*

- *An **<u>autonomous/self-driving vehicle</u>** is capable of observing the surroundings and driving, in certain situations, without human input. Currently, it can perform many driving tasks on many roads, under most conditions, without a driver.*
- ***Paratransit services** are door-to-door services for people with disabilities.*
- ***Community transportation** is a traditional transportation service in the community where you live (for example, a community van or shuttle).*

Demographics
First, please tell us a little bit about yourself:

1. What is your current gender identity?
   - ☐ Male
   - ☐ Female
   - ☐ Other __________

2. Please indicate your age: ______
   - ☐ Prefer not to answer

3. Please indicate your race/ethnicity (Select all that apply):
   - ☐ American Indian or Alaska Native
   - ☐ Asian
   - ☐ Black or African American
   - ☐ Hispanic or Latino
   - ☐ Native Hawaiian or Other Pacific Islander
   - ☐ White
   - ☐ Other___________

4. What is the highest degree or level of school you have completed?
   - ☐ Less than 9th grade
   - ☐ 9th to 12th grade, no diploma
   - ☐ High school graduate or GED
   - ☐ Some college, no degree
   - ☐ Associate's degree
   - ☐ Bachelor's degree
   - ☐ Master's degree
   - ☐ Doctoral degree
   - ☐ Prefer not to answer

5. What is your current employment situation? (Please select all that apply.)
   - ☐ Work Part-time
   - ☐ Work Full-time
   - ☐ Not employed
   - ☐ Retired
   - ☐ Military Veteran
   - ☐ Full-time Student
   - ☐ Disabled/ not able to work
   - ☐ Other_________

6. What is your annual household income?
    - ☐ Under $25,000
    - ☐ $25,000 - $49,999
    - ☐ $50,000 - $74,999
    - ☐ $75,000 - $99,999
    - ☐ $100,000 - $149,999
    - ☐ $150,000 or more
    - ☐ Prefer not to answer

7. Do you have any impairments that impact your use of transportation? If so, please select all that apply:
    - ☐ Physical (for example, unable to turn neck or maintain pressure on the brake or gas pedal)
    - ☐ Vision (for example, difficulty driving at night)
    - ☐ Hearing (for example, deafness)
    - ☐ Cognitive (for example, difficulty paying attention while driving)
    - ☐ Psychological (for example, anxiety in heavy traffic)
    - ☐ None of these
    - ☐ Prefer not to answer

8. Do you have a Smartphone (i.e., a mobile phone that performs many of the functions of a computer)?
    - ☐ Yes
    - ☐ No
    - ☐ Not sure

9. Do you own a working motor vehicle, such as a car, truck, or motorcycle?
    - ☐ Yes
    - ☐ No

10. Do you have a valid driver’s license?
    - ☐ Yes
    - ☐ No

Modes of Transportation

Next, we have some questions about your experiences with various types of transportation. Please refer to Figure 1 on page 1 for a definition of transportation options.

11. How familiar are you with the following types of transportation?
    Select level of familiarity for each mode of transportation:

	Not familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
Autonomous vehicles	☐	☐	☐	☐	☐
Autonomous taxis	☐	☐	☐	☐	☐
Autonomous shuttles	☐	☐	☐	☐	☐
Ridesourcing services	☐	☐	☐	☐	☐
Ridesharing services	☐	☐	☐	☐	☐

12. How often have you used the following modes of transportation?
    Provide response for each mode of transportation:

	Often	Rarely	Never
Autonomous vehicle	☐	☐	☐
Autonomous taxi	☐	☐	☐
Autonomous shuttle	☐	☐	☐
Ridesourcing service (Uber, Lyft, Taxi)	☐	☐	☐
Ridesharing service (carpool, etc.)	☐	☐	☐
Autonomous ridesharing service	☐	☐	☐
A traditional vehicle with active safety systems or driver-assistance systems (for example: adaptive cruise control, lane departure warning, parking assist, etc.)	☐	☐	☐

13. Which modes of transportation are ***available*** to you? Select all that apply:
   - ○ Drive myself
   - ○ Share a ride with family
   - ○ Share a ride with friends
   - ○ Walking
   - ○ Bicycling
   - ○ Public transit
   - ○ Golf cart
   - ○ Ridesourcing
   - ○ Paratransit
   - ○ Ridesharing
   - ○ Community transportation service in the community where I live
   - ○ Autonomous vehicle
   - ○ Other________

14. In the last three months, how have you traveled to each of the following destinations? For each destination, please indicate your primary mode of travel (noted across the top row of the table below):

Destination	**Drove yourself**	**Rode with family**	**Rode with friends**	**Walked**	**Biked**	**Public transit**	**Golf cart**	**Ridesourcing**	**Paratransit**	**Ridesharing**	**Community transportation**	**Autonomous vehicle**	**Other**	**Not applicable**
Work	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Volunteering	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Shopping, running errands, etc.	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Medical appointments, etc.	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Physical activity, exercise, etc.	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Social Activities	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Dining out	O	O	O	O	O	O	O	O	O	O	O	O	O	O

15. In a typical week, what is your primary means of travel?
    - ☐ Drive myself
    - ☐ Share a ride with family
    - ☐ Share a ride with friends
    - ☐ Walking
    - ☐ Bicycling
    - ☐ Public transit
    - ☐ Golf cart
    - ☐ Ridesourcing
    - ☐ Paratransit
    - ☐ Ridesharing
    - ☐ Community transportation service in the community where I live
    - ☐ Autonomous vehicle
    - ☐ Other________

16. Why is this your preferred mode of transportation? Select all that apply:
    - ○ I don't have access to public transportation in my area
    - ○ The public transportation isn't good enough
    - ○ Access to ridesourcing services is limited in my area
    - ○ I prefer to be independent
    - ○ It is more comfortable
    - ○ It is more relaxing
    - ○ It is more enjoyable
    - ○ I need it for long-distance travel
    - ○ I need it for transporting equipment
    - ○ I need it to drive my family members
    - ○ I prefer the privacy
    - ○ I can control my own schedule
    - ○ It is faster
    - ○ It is safer
    - ○ It is cheaper
    - ○ I am not interested in reducing my car use
    - ○ Other ____________

16A. If you selected multiple reasons for Item 16, **which of these reasons is the single most important factor?**

- ☐ I don't have access to public transportation in my area
- ☐ The public transportation isn't good enough
- ☐ Access to ridesourcing services is limited in my area
- ☐ I prefer to be independent
- ☐ It is more comfortable
- ☐ It is more relaxing
- ☐ It is more enjoyable
- ☐ I need it for long-distance travel
- ☐ I need it for transporting equipment
- ☐ I need it to drive my family members
- ☐ I prefer the privacy
- ☐ I can control my own schedule
- ☐ It is faster
- ☐ It is safer
- ☐ It is cheaper
- ☐ I am not interested in reducing my car use
- ☐ Other ____________

17. Which of the following issues impact your choices about various types of transportation? Please select all that apply:

- ○ Do not own a working vehicle
- ○ Do not have a valid driver's license
- ○ Can't drive due to medical condition
- ○ Can't drive due to physical condition
- ○ Prefer not to drive at night
- ○ Prefer not to drive in heavy traffic
- ○ Need assistance getting in and out of vehicle
- ○ Require a wheelchair lift
- ○ Require a ramp
- ○ Require space for an assistive device (e.g., walker, wheelchair, etc.)
- ○ Public transportation service is limited
- ○ Do not feel safe using public transportation
- ○ Do not feel safe using a hired service (taxi, Uber, Lyft, etc.)
- ○ Do not know how to use a hired service (taxi, Uber, Lyft, etc.)
- ○ Do not have the means to use a hired service (taxi, Uber, Lyft, etc.)
- ○ Other issue (please describe):
- ○ None of these
- ○ Not sure

18. In the last 3 months, have you driven a motor vehicle (such as an automobile, van, or motorcycle)?
    - ☐ Yes
    - ☐ No (If selected, skip to #19)

    18A. On average, how many hours do you spend per week driving to and from work?
    - ☐ _______
    - ☐ Not applicable, I do not work
    - ☐ Not applicable, I work remotely
    - ☐ Not sure

    18B. On average, how many hours do you spend per week driving for trips other than work? [If none, please enter "0"]
    - ☐ _______
    - ☐ Not sure

19. Have you ever requested a ride from ridesourcing services (for example Uber, Lyft, etc.)?
    - ☐ Yes
    - ☐ No (If selected, skip to 20)

    19A. On average, how many times per week do you use ridesourcing services?
    - ☐ ______
    - ☐ 1 to 3 times per month
    - ☐ Less than once per month
    - ☐ Not sure

Perceptions of Transportation Options

Next, we have some questions about your transportation options and perceptions of autonomous vehicles, ridesourcing services, and ridesharing services.
As you complete this section, please refer to Figure 1 (on page 1) for definitions:

<ins>Directions:</ins> *Please place a vertical dash (/) on the scale to display the degree to which you agree or disagree with the statement.*

20. I would use an autonomous/self-driving vehicle

Strongly Disagree ________________________________ Strongly Agree

21. I will use an autonomous vehicle ridesharing service if it is handicap accessible

Strongly Disagree ________________________________ Strongly Agree

22. Riding in an autonomous vehicle is safe

Strongly Disagree ———————————— Strongly Agree

23. Driving my vehicle near autonomous vehicles is safe

Strongly Disagree ———————————— Strongly Agree

24. Autonomous vehicles will decrease the number of crashes

Strongly Disagree ———————————— Strongly Agree

25. Autonomous vehicles will reduce the severity of injuries in crashes

Strongly Disagree ———————————— Strongly Agree

26. I would encourage family members to use autonomous vehicles

Strongly Disagree ———————————— Strongly Agree

27. I trust the technology in an autonomous vehicle more than I trust the technology of a standard vehicle.

Strongly Disagree ———————————— Strongly Agree

28. I trust a driver in an autonomous vehicle more than I trust a driver of a standard vehicle

Strongly Disagree ———————————— Strongly Agree

29. I would use an autonomous shuttle

Strongly Disagree ———————————— Strongly Agree

30. I would rideshare with people that I don't know, if it reduces my costs

Strongly Disagree ———————————— Strongly Agree

31. I would encourage family members to use ridesourcing services

Strongly Disagree ———————————— Strongly Agree

32. I am willing to use a ridesharing autonomous vehicle

Strongly Disagree ———————————— Strongly Agree

33. Under which of the following conditions are you willing to use an autonomous vehicle? Select all that apply:
    - If there is an operator in the driver's seat monitoring vehicle operations
    - If there is an operator in the vehicle who can answer my questions
    - If the vehicle is remotely monitored by an operator
    - If I can communicate with an operator that is working remotely
    - None of the above

34. Which of the following types of autonomous vehicles would you use? Select all that apply:
    - Privately owned autonomous vehicle
    - Shared-ownership autonomous vehicle
    - A public autonomous vehicle (for example, autonomous shuttle)
    - A ridesharing autonomous vehicle
    - None of the above
    - Not sure
    - Prefer not to answer

35. Autonomous vehicles will allow me to stay active

Strongly Disagree ———————————— Strongly Agree

36. Autonomous vehicles will enhance my quality of life

Strongly Disagree ———————————— Strongly Agree

37. Autonomous vehicles will reduce traffic congestion

Strongly Disagree ———————————— Strongly Agree

38. I would not mind having a longer travel time if I can engage in other tasks (for example, watching a video or reading a book) while riding in an autonomous vehicle.

Strongly Disagree ———————————— Strongly Agree

39. I would be willing to pay more than the price of a traditional vehicle to purchase a fully self-driving autonomous vehicle

Strongly Disagree ———————————— Strongly Agree

39A. What percentage of money would you be willing to pay (as a one-time cost), beyond the typical purchase price of a traditional vehicle, to purchase a fully self-driving autonomous vehicle?

- ☐ ____%
- ☐ Not sure

40. I would be willing to pay more than the standard price of a traditional transportation services (like a shuttle, bus, or taxi) to ride in a fully self-driving autonomous vehicle

Strongly Disagree ———————————————— Strongly Agree

IF AGREE:
40A. How much more would you be willing to pay per mile for the use of a public autonomous vehicle?

- ☐ _______
- ☐ Not sure

41. Autonomous vehicles are designed for people like me

Strongly Disagree ———————————————— Strongly Agree

42. Autonomous vehicles will provide more travel options in areas with insufficient transit services

Strongly Disagree ———————————————— Strongly Agree

43. Autonomous **vehicles** will be easy to use

Strongly Disagree ———————————————— Strongly Agree

44. Autonomous vehicles will increase mobility for those who are currently incapable of driving

Strongly Disagree ———————————————— Strongly Agree

45. Shared use of autonomous vehicles will provide better access to transportation for those that currently have barriers to transportation

Strongly Disagree ———————————————— Strongly Agree

46. Autonomous ridesharing services will be easy for individuals with physical limitations to use

Strongly Disagree ———————————————— Strongly Agree

47. Autonomous ridesourcing services will be easy for individuals with physical limitations to use

Strongly Disagree ——————————————— Strongly Agree

48. Autonomous **shuttles** will be easy to use

Strongly Disagree ——————————————— Strongly Agree

49. I am concerned about the following issues related to autonomous vehicles: (Select all that apply)

- ○ Autonomous vehicles do not drive as well as human drivers
- ○ Legal liability in case of a crash
- ○ Data privacy (e.g., location, destination tracking)
- ○ Interactions with other road users
- ○ Sensor equipment failure
- ○ Computer system failure
- ○ None of the above
- ○ Other__________
- ○ Not sure
- ○ Prefer not to answer

Finally, we'd like you to share your thoughts with us about autonomous vehicles.

50. Are there any other comments or thoughts you'd like to share about autonomous vehicles or any other topic addressed in this survey?

Thank you for your valuable time and participation. The information you have provided is very useful to the Florida Department of Transportation as we all work together to shape the future of transportation.

If you are interested in learning the final results, please visit our website: