Approaching autonomous shuttle pilot programs in public transportation

by

Alicia Hunter

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF REGIONAL & COMMUNITY PLANNING

Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning, and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2018

Approved by:

Major Professor
Gregory Newmark, Ph.D.

Copyright

Abstract

Investment, research, and development of autonomous vehicles grows each year. As the years pass, more and more transit agencies are interested in incorporating autonomous vehicles as a public transit service. However, there are still unknowns and uncertainties as to the safety and viability of autonomous vehicles. For transit agencies to incorporate autonomous vehicles in public transit, agencies need to validate the application of autonomous vehicles in real-world scenarios and environments. One option for testing the vehicles is for transit agencies to implement an autonomous shuttle pilot program. A pilot program will give agencies an opportunity to learn if and how autonomous vehicles can enhance or improve transit services. Even though autonomous shuttle pilot programs have been deployed worldwide, there has been little comparative analysis. This report addresses the need for knowledge by providing practical considerations of essential pilot program elements. To assist transit agencies, this report illustrates previously executed autonomous shuttle pilot programs, identifies the core elements of a pilot program, and discusses the relationship between elements. To accomplish these tasks, this report reviews nine European autonomous shuttle pilot programs, literature surrounding the topic, and interviews key personnel associated with the pilot programs. The results of this research help transit agencies make informed decisions about approaching autonomous shuttle pilot programs in public transportation.

Table of Contents

List of Figures

List of Tables

Acknowledgments

Thank you to my committee members: Dr. Greg Newmark of Regional & Community Planning, Department Head Stephanie Rolley of Landscape Architecture and Regional & Community Planning, and Dr. Jida Wang of Geography. I express gratitude to the fellow researchers and professionals who provided their time and valuable information. Thank you as well to KCATA who has served as the spark of inspiration for this topic. With a special thanks to my family and friends for their support and encouragement.

Dedication

With undeniable appreciation, I dedicate this to my husband, Matthew Ross, who has been astonishingly patient and shown unwavering support in my pursuits.

Chapter 1 - Introduction

Applications of autonomous shuttles are occurring worldwide in varying levels of development. To date, Europe has produced the most autonomous shuttle pilot programs (insert table to support). The United States' approach to autonomous vehicles has been sluggish due to several questions, concerns, and issues involving: acceptance, liability, safety, regulations, and costs. At a federal level, the United States has not established a universal, definitive plan for the use and regulation of autonomous vehicles (B. V., Singh, and Tare 2017). At the state level, some states have been more proactive in supporting the implementation while others remain absent. At the local level, transit agencies are interested and invested in autonomous shuttles, with some having executed pilot programs and demonstrations. Regardless of the varying extents of autonomous shuttle applications throughout the United States, advancements in autonomous vehicles are continuing. For the advancement of autonomous shuttles in public transit, it requires careful planning, knowledge, and answers to the uncertainties involved with its implementation. Fagnant and Kockelman (2015) state, unanswered questions will delay and influence the nation's ability to successfully plan for autonomous vehicles in transportation systems. For transit agencies to successfully approach and implement autonomous shuttles, they require research of the performance of pilot programs. Pilot programs, demonstrations, and deployments of autonomous shuttles offer agencies learning opportunities (Polzin 2016). Transit agencies need research conducted on those programs and deployments that recommends best practices for approaching the application of autonomous shuttles. This research aims to assist transit agencies more efficiently plan for autonomous shuttle implementations.

There are existing reports that provide evaluations on autonomous shuttle pilot programs. However, such reports do not provide a comprehensive analysis and comparison of multiple pilot programs. This report addresses the knowledge gap of a comprehensive approach to autonomous shuttle pilot programs for transit agencies. This report responds to the need for information by combining a review of the limited literature with interviews of principal participants of pilot programs. This report identifies three essential elements gathered from nine autonomous shuttle pilot programs: site selection, program design, and partnerships. The pilot programs in this report were shortlisted based on seven criteria: start date, completion date, duration, access, vehicle type, automation capabilities, and available information. The essential elements identified from the research will support an implementation framework and recommend best practices for transit agencies. At the conclusion, this report will answer: what elements and considerations are necessary for transit agencies to implement and autonomous shuttle pilot program in public transportation?

Chapter 2 - Literature Review

Deployment Predictions

There is a belief that fully autonomous cars will target consumers and be implemented as personal vehicles first. However, Hars (2016) states that those who believe that are making the assumption that autonomous vehicle manufactures will target consumers. Complexities such as liability, safety, legal constraints, and legislation create barriers; they are delaying the integration of autonomous vehicles making consumers an unlikely target. Also, autonomous vehicles do not have experience with operating in the infinitely possible complex scenarios and environments of streets. Table 1 describes each level of automation. Level 5 automation navigates its surrounding on any road in any condition with no driver assistance. Since high levels of automation need to be familiar with the environment it operates in; it brings about the difficult task of programming personal autonomous vehicles to handle all weather conditions and road types present across the world (Hars, 2016). However, there are scenarios in which it is possible for level four and five automated vehicles to operate without having to take on the daunting task of programming a vehicle to handle every complex scenario and environment. An autonomous shuttle pilot program that operates with supervision and restriction is a way to demonstrate the potential capabilities of the technology in public transportation. Implementing a supervised automated shuttle with operational restrictions like low-speed and pre-defined routes reduces the risks associated with highly automated vehicles. With risks mitigated, autonomous shuttles become a more viable option for implementing the emerging technology (Smith, 2014). As Smith (2014), suggests, deploying autonomous shuttles allow for testing of higher levels of automation and is "well suited for airports, city centers, business clusters, university campuses… and last-mile transit applications". The International Transport Forum (ITF) (2015) reports that deployment of level five vehicles will occur in two ways; one being the incremental technical upgrades of automated driving in conventional vehicles and the second being the deployment of automated vehicles that increase its system and operations to more complex situations. ITF defines these two ways of deployment as the “something everywhere” and “everything somewhere” strategies. It is with the “everything somewhere” strategy that high levels (levels 4 and 5) of automation occur. This strategy allows a vehicle to operate with automation and without a driver but only be deployed in specific environments. Other reports state that the development and deployment of autonomous vehicles are targeting taxi and car-share operators and transit agencies. Programming and mapping small areas like office parks and airports are more manageable for transit agencies and taxi and car-share operators (Hars, 2016). The integration of autonomous vehicles will likely come in the form of fleet vehicles and buses (DuPuis, Martin, and Rainwater, 2015). The strategy of targeting consumers with the deployment of autonomous vehicles is hindered by several factors. However, those factors can be mitigated when autonomous shuttles are deployed in public transit and fleet applications (Table 2). “The institutional environment of public transportation, the high use and exposure of public transit vehicles, and the professional operator and maintenance environment make them attractive testbeds to deploy emerging technologies with the public transportation industry” (Polzin, 2016). Because autonomous vehicles need real-world driving scenarios in controlled environments, transit agencies and fleet operations (e.g., shuttles, car-sharing, taxis, and buses) can provide those type of scenarios and environments.

Table 1 Levels of Automation

Levels	Automation	Definition	What does it mean?
0	No Automation	The driver is in complete and sole control of the primary vehicle controls (brake, steering, throttle, and motive power) at all times, and is solely responsible for monitoring the roadway and for the safe operation of all vehicle controls.	Zero autonomy; the driver performs all the driving tasks
1	Driver Assistance	Involves one or more specific control functions; if multiple functions are automated, they operate independently from each other. The driver has overall control and is solely responsible for safe operation, but can choose to cede limited authority over a primary control.	The vehicle is controlled by the driver, but some advanced driver assistance systems may assist the driver (e.g., steering and braking).
2	Partial Automation	Involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. Vehicles at this level of automation can utilize shared authority when the driver cedes active primary control in certain limited driving situations. The driver is still responsible for monitoring the roadway and safe operation and is expected to be available for control at all times and on short notice.	The vehicle has combined automation functions (e.g., acceleration and steering), but the driver must remain engaged and monitor the environment at all times.
3	Conditional Automation	Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions to rely on the vehicle to monitor changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficient transition time.	A driver is needed but not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.
4	High Automation	Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions to rely on the vehicle to monitor changes in those conditions even if a human does not respond appropriately to intervene.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.
5	Full Automation	The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. By design, safe operation rests solely on the automated vehicle system.	The vehicle is capable of performing all driving functions under all conditions. The human occupants are just passengers but may have the option to control the vehicle.

Source: NHTSA, Definitions – Levels of Vehicle Automation

Table 2 Factor influencing the deployment of autonomous vehicles

Issue of AV Deployment in Consumer Vehicles	Factor	Benefit of AV Deployment in Transit and Fleet
The high upfront costs that are regularly associated with new technology will make purchasing fully autonomous vehicles for private consumers unappealing or unattainable (Fagnant & Kockelman, 2015).	**Affordability**	Operator labor makes up a large portion of bus transit operating costs for transit agencies and autonomous vehicles could reduce the need for onboard operators (Polzin, 2016).
Giving up full control and placing complete trust in an emerging technology is rightfully off-putting. Many people will not want to jeopardize their safety and will not be accepting of owning a personal fully autonomous vehicle (Arem, et al., 2017).	**Acceptance**	Small-scale testing and demonstrations will gradually expose people to the technology; Also, they serve as a platform for educating and informing people on how the technology works.
With autonomous vehicle sold to consumers, the vehicles are dispersed across the country (Hars, 2016). When the manufactures need to make updates or recalls, reaching those vehicles promptly is crucial to upholding the utmost safety of the consumer.	**Maintained Control**	Fleet owners and transit operators will maintain control and have access to the autonomous vehicles at all times which allows for continued monitoring, regular updates and improvements, and identifying and remedying issues quicker, all of which are important when deploying such advance and unfamiliar technology (Hars, 2016). Transit agencies provide the controlled environments necessary for technology validation and deployment (Polzin, 2016).

User Perception, Preference, Experience

Although pilot programs are occurring worldwide, few people have experience interacting with an autonomous shuttle. The increasing interest and development of autonomous vehicles will affect how travelers interact with public transportation systems (Fagnant & Kockelman, 2015). Some surveys analyze the experience of those who have interacted with autonomous shuttles while some reports evaluate peoples' perception of and preference for autonomous shuttles. With the increase in autonomous shuttle pilot program implementations, researchers will have more information to report on that can more accurately depict the perceptions and experiences of autonomous shuttle users.

A report produced by Arem, et al. (2017), studied people's first perception when riding in an autonomous shuttle on the semi-public roads of a campus in Berlin, Germany. The survey in Arem's report had 318 respondents, and it identified that there was a positive response towards autonomous shuttles in public transportation. A survey of slightly over 1,500 respondents from the United States, United Kingdom, and Australia, revealed that 73.6% of people were very or moderately concerned about autonomous vehicles in public transportation (Schoettle & Sivak, 2014). While the results of the first survey illustrate general acceptance of autonomous shuttles in public transportation, the second survey shows strong concern. However, the difference in opinion can be attributed to the type of interaction that the participants had with the autonomous shuttles. The respondents of the U.S., U.K., and Australia survey were not interviewed after an interaction with an autonomous shuttle whereas the study by Arem, et al. (2017) surveyed people who did have an interaction. The survey defines interaction as a driver, cyclists, or pedestrian who shared the road with an autonomous shuttle. Comparing the survey results of Schoettle & Sivak, 2014 with Arem, et al. (2017), reveals that perception and experience yield different opinions towards autonomous shuttles in public transportation. Only a few number of people have interacted with autonomous shuttles in real traffic environments. The lack of interaction accounts for the varied opinions and information on whether a person will use these vehicles (Arem, et al., 2017).

It is important to mention that the shuttles that people interacted with operated at level 4 automation and not level 5 automation. An autonomous shuttle is not a typical mode of transportation, people are not familiar with the system, and their interactions and behavior will not be typical of familiar (Lohmann & Van der Zwaan, 2017). If those how were surveyed rode in a shuttle that operated on its own without human input their reactions and the survey results could be different. Be wary of potential false data results when surveying individuals about there experience or preference for automated or autonomous shuttles

Existing Reports Evaluating Pilot Programs

Existing reports and evaluations of autonomous shuttle pilot programs are limited. There were some inconsistencies between the reports and documentation. Examples of some inconsistencies noticed by the researcher included a difference in deployment dates, number of shuttles, and length of the route. Inconsistencies aside, this section discusses the reports with the most complete synopsis and analysis.

Pessaro (2016) published the report "Evaluation of Automated Vehicle Technology in Transit." The report is an updated version of its previous 2015 release. Pessaro's report provides a summarization of the status of automated vehicles. Similar to this report, Pessaro wanted to help transit agencies. However, his report was more focused on cataloging automated vehicle pilot programs and shuttle manufactures and was sponsored by the National Center for Transit Research. The cause for an updated report was largely due to Europe's multi-city automated shuttle pilot program under the project name CityMobil2. Pessaro's report also examines two other pilot programs in Europe known as WEpods and CarPostal, and two Unites States pilot programs with Contra Costa Transportation Authority (CCTA) and Minnesota Valley Transit Authority (MVTA). This report does not examine the CarPostal, CCTA, or MVTA pilot programs because the project did not meet the predefined evaluation criteria (see Chapter 3 for criteria list). At the time of this report, the CarPostal pilot did not have adequate information detailing the program. The CCTA pilot program is not scheduled to transport passengers until phase three, which will occur after the completion of this report. The MVTA program is not testing level 4or level 5 automated shuttles.

While Pessaro's report provides an overview of five pilot programs, this researcher identified a discrepancy in his report. The discrepancies appear when Pessaro refers to the operation of the shuttles in CityMobil2's LaRochelle pilot program and WEpods pilot program. When referring to the LaRochelle pilot program Pessaro states, "the vehicles were in autonomous mode 94% of the time during demonstration," and when referring to the WEpods pilot, he states, "the WEpods will operate autonomously" (Pessaro, 2016). CityMobil2 reports that the operation of their shuttles are not autonomously but automated instead (CityMobile2, 2016) (Holguin & Stam, 2016). Similarly, the WEpod shuttles operated in an automated mode (Van der Wiel, 2017). The discrepancy here is in his use of autonomous when he refers to the operation of the shuttle. By Pessaro's (2016) own definition, an autonomous vehicle is capable of sensing its environment and navigating without human input. The terms autonomous vehicle and automated vehicle have been used interchangeably in many reports, blogs, websites, and the like. However, there is a difference in capability. The shuttles in the CityMobil2 and WEpods pilot programs operated on scheduled predefined routes and required human intervention and control of some functions. According to the Society of Engineers, these shuttles did not operate autonomously (level 5 automation). For clarification, the shuttles used in the CityMobil2 and WEpods pilot program can operate autonomously, but the projects chose to test the shuttles at level 4 automation. Nonetheless, the information gathered from such pilot programs is beneficial for future application. As Pessaro states, “with each demonstration project the body of knowledge on shared autonomous vehicles is expanding” (Pessaro, 2016).

The CityMobil2 project produced a report of their own titled, “Experience and Recommendations,” which is similar to the intent of this report. CityMobil2’s report details the purpose of the project and provides their approach, what they learned, what to expect, and makes recommendations for future policies about automated shuttles. This report differs from the CityMobil2 report in two ways. First, this report includes pilot programs implemented outside of the CityMobil2 project. By comparing pilot programs beyond those conducted by CityMobil2, those interested in conducting a pilot program will have more examples to cite. Secondly, while this report is not a comprehensive evaluation of all programs and all components of a pilot, it does identify the essential elements needed based on the experience of other pilot programs. By defining and analyzing the essential elements, transit agencies interested in an autonomous shuttle pilot program will receive an in-depth analysis of how certain choices affect the outcome and capabilities of a pilot program. The CityMobil2 report provides a good synopsis of their project while this report provides transit agencies with information they need to make informed decisions about the design elements of their pilot program.

Chapter 3 - Methodology

Research Question

Public transit agencies are interested in whether or not autonomous shuttles can improve transit services and reduce transit costs. Some autonomous shuttle pilot programs have been introduced, but to date, there has been no comparative analysis of these programs. The lack of a comparative review hinders the ability of public transit agencies to make informed decisions about designing their autonomous shuttle pilot programs. This lack of information leads us to ask: what elements and considerations are necessary for transit agencies to implement and autonomous shuttle pilot program in public transportation?

Process

Figure 1 shows the location of the nine pilot programs this report is researching. All nine pilot programs are located in Europe and were selected based on a predefined list of criteria:

1. Started on or after January 1st, 2014
2. Completed by December 31st, 2017
3. A duration of at least four weeks
4. Open to the public and transports passengers
5. Vehicle type must be a shuttle with a minimum carrying capacity of six passengers
6. The shuttle must be capable of operating at level 4 automation
7. Available information

Figure 1 Map of pilot program locations

While a variety of autonomous vehicle pilot programs have been implemented around the world, not all pilot programs apply to this report. Because technology evolves continuously and adapts into a better version of itself, this researcher chose a start date of no later than 2014. Autonomous shuttles implemented between 2014 and 2017 will more closely represent the current capabilities of high levels of automation. Another criterion for the pilot programs was requiring the shuttle to operate for at least four weeks. This researcher believes that proper analysis and data collection occurs best when the shuttle is allowed to experience a variety of scenarios that can only occur naturally with time. For a pilot program to make the shortlist of this report, it must be open to the public and transport passengers. Also, the autonomous vehicle has to be a shuttle vehicle with a minimum carrying capacity of six passengers. A shuttle is a vehicle that offers a shared-ride service for people and regularly travels between two points. Another requirement for the pilot programs is that the shuttle is capable of operating at level 4 automation. It is at level 4 that the shuttle begins to monitor and navigate the environment without a human driver. The final and equally significant criterion for the pilot programs is the availability of data and information. Finding available resources that provide a respectable amount of knowledge on autonomous shuttle applications in public transportation has proved to be difficult.

Data for this report was collected from a variety of resources and interviews responses. Obtaining information about autonomous shuttle pilot programs was more difficult than anticipated. While there are many mentions and press releases about autonomous shuttle testing, there are few reports that provide in-depth information. After a review of the available information, it was determined that interviewing key personnel was required to enlighten the analysis of this report. Key personnel includes professionals who participated in organizing an autonomous shuttle pilot program, or who studied its implementations. To substantiate this report, the interviewed participants were asked to direct the research team to additional written resources on the pilot programs.

Interviews

Potential interviewees were identified as listed contact persons on specific pilots, by contacting sponsoring agencies in the absence of a listed contact person, and through recommendations of other principal organizers. The criteria of selecting desired personnel were those who were actively involved as an organizer of an autonomous shuttle pilot program, or studied the implementation of such program, and may be from public agencies, private operators, autonomous vehicle manufacturers, or sponsoring agencies, such as universities or major employers. The interview used a structured open-ended protocol to learn about the experiences of the selected pilot programs. Appendix B shows a sample interview protocol and questionnaire.

Of the nine identified principal personnel, three were interviewed. One interview was conducted via email, one via telephone, and one via teleconferencing. By analyzing the interview responses, this report identifies specific elements and considerations necessary for implementing a pilot program for autonomous shuttles.

This report makes its best effort to provide accurate information and analysis about the implementation of autonomous shuttle pilot programs, based on the accuracy and availability of information.

Chapter 4 - Background

Autonomous Shuttle Specifications

All the pilot programs examined for this report utilized electric shuttles supported by Easymile, a partnership of Ligier Group and Robosoft (2015). Easymile is a French-based autonomous vehicle manufacturing company founded in 2014. Easymile manufactures the EZ10 autonomous shuttle and provides technical software and fleet management for autonomous shuttles.

Figure 2 Easymile EZ10 shuttle
Source: Easymile, 2018

The EZ10 shuttle is 100% electric, travels up to 27.9 mph, and carries up to 15 passengers (Figure2). The shuttle is equipped with a built-in handicap-accessible ramp. The EZ10 shuttle uses GPS tracking systems, visual guidance technology and collision detection systems. The battery can operate a shuttle for up to 14 hours, in normal conditions. The EZ10 is capable of operating in three different modes: metro, bus, and on request (Industrial Innovation and Diversification for Ligier Group, n.d.). Metro mode allows the shuttle to operate systematically on a predefined route and stops at each station. The bus mode operates like the metro mode, but users can request a stop at a station. The third mode, known as on request, allows the user to request a shuttle and the operating system determines the best route. The autonomous shuttles tested in the pilot programs discussed in this report utilized onboard operators and operated in an automated mode, or metro/bus mode.

The shuttles used in the pilot programs this report examines can operate at level 5. As in the CityMobil2 pilot programs, their autonomous shuttles depend on external communications (e.g., coming from other vehicles or the operator) and cannot be considered autonomous (CityMobile2, 2016). As previously mentioned, because of the uncertainties and complex scenarios the shuttles were not tested past level 4 automation. Sub-section "Automated Trials to Autonomous Applications," in Chapter 6, expands on how transit agencies can transition from level 4 automation to fully autonomous.

Pilot Program Projects

Pilot programs give companies, researchers, investors, and transit agencies opportunities to test, on a small-scale, the effectiveness of a system and identify any implementation challenges. Because of its complexity and potential impacts, testing autonomous shuttle through pilot programs allows transit agencies to gauge the feasibility of incorporating autonomous shuttles as part of their transit services. With a small-scale pilot program and operational restrictions (e.g., reduced speed) of an autonomous shuttle, transit agencies can gradually expose and familiarize the public with the emerging technology (Arem, et al., 2017).

Autonomous shuttles can provide adequate public transportation for cities by addressing the first-mile-last-mile problem. The first-mile last-mile problem occurs when “destinations are too far away to comfortably walk to transit stops”; it is difficult and unsafe (Zaccaro, 2017). A shuttle can provide short trips to and from transit stops. Having that increased accessibility could potentially enhance transit ridership. Also, labor costs for transit operators can account for 60% percent of public transportation operating costs (Dickens & Neff, 2017). Depending on the fleet management configuration for an autonomous shuttle, transit agencies could increase their transit services without having to endure the cost of labor associated with operating costs.

Table 3 provides an overview of the nine pilot programs this report examines. The pilot programs are ordered alphabetically by system location. Seven programs are part of a larger project in Europe known as the CityMobil2 project. The Province of Gelderland initiated one pilot project known as WEpods. The Appelscha Municipality initiated the final program. All pilot programs offered shuttle services free of charge to the public.

Table 3 Pilot program overview

System Location		Primary Project Organizer	Start Date	Program Duration (Approx. in weeks)	Route Length (miles)	Total # of Riders
City	Country					
Appelscha	Netherlands	Municipality of Appelscha	13-Sep-2016	7	1.55	500
LaRochelle	France	CityMobil2	17-Dec-2014	16	1.18	14,660
Lausanne	Switzerland	CityMobil2	17-Apr-2015	20	0.62	7,000
Oristano	Italy	CityMobil2	17-Jul-2014	28	0.81	2,580
San Sebastian	Spain	CityMobil2	1-Apr-2016	12	0.75	2,750
Sophia Antipolis	France	CityMobil2	1-Feb-2016	16	0.93	4,059
Trikala	Greece	CityMobil2	10-Nov-2015	12	1.55	12,150
Vantaa	Finland	CityMobil2	10-Jul-2015	4	0.53	19,021
Wageningen	Netherlands	Province of Gelderland	1-Jun-2016	36	4.97	1,000

CityMobil2

CityMobil2 is a major European project funded by the European Union for research and technology development of automated transportation. One of the project's objectives was to demonstrate the feasibility of integrating automated shuttles in urban environments. With a budget over 18.4 million dollars (approximately 15 million Euros), partnerships with over 45 stakeholders, and a timeline of four years (2012 – 2016), the CityMobil2 demonstration project transported over 60,000 passengers.

The project established a Project Management Committee who were responsible for selecting the winning bids for sites that will implement automated shuttle demonstrations. CityMobil2's implementation process took between 12 and 15 months by following seven successive steps: diagnostic phase, the definition of objects and impacts, intra-city site selection, initial evaluation, the design of the system, ex-ante evaluation, and system deployment phase. The CityMobil2 project also included showcases at three other sites located in Spain, France, and Poland, which ran for two or three days. The purpose of a showcase was to raise awareness for the automated technology and its potential benefits to the community. The three showcase events do not meet the minimum qualifications defined by the researcher and are not discussed in this report.

CityMobil2 conducted evaluations and collected data for five of its automated shuttle pilot programs. Also, CityMobil2 interviewed and surveyed shuttle passengers, other road users, the general public, and decision makers. A dedicated logging system was in place to automatically record vehicle performance data, sensor data, and camera data of road and traffic conditions. The following sections provide further information about CityMobil2's seven pilot programs in La Rochelle, France; Lausanne, Switzerland; Oristano, Italy; San Sebastian, Spain; Sophia Antipolis, France; Trikala, Greece; and Vantaa, Finland.

La Rochelle

The La Rochelle pilot program took place from December 2014 to April 2015. Mercier-Handisyde, (2014) reports a one month set-up period was required to prepare and test the shuttles and systems for the pilot. The pilot program was organized into three phases using a total of six autonomous shuttles. The first phase deployed three shuttles with a segment route connecting the Aquarium and Tourist Office. The second phase deployed the remaining three shuttles on a segment connecting the LaRochelle Technoforum (University) and a library. Figure 3 shows the final third phase of the pilot, which connects the first segment with the second segment. The program experienced a delay in delivery of the final three shuttles. Because of the delivery delay, the final route was operational for only a month. Once all shuttles were delivered, the peak hours required the use of six shuttles while the off-peak hours utilized four shuttles. A round trip ride took approximately 55 minutes. The LaRochelle system made adjustments to its infrastructure. Infrastructure changes included: the removal of several on-street parking spaces, road markings, installation of traffic lights at six intersections (which gave priority to the shuttle), and installation of boarding stations at the stops (Appendix C).

An onboard operator was present at all times and ready to take over control if needed during shuttle testing. CityMobil2 reported a few malfunctions that required the onboard operator to take manual control of the shuttle but did not provide any further information. However, CityMobil2 noted that external factors such as illegal parking, road construction, and unclear road markings negatively affected the efficiency and capabilities of a fully autonomous shuttle (Pessaro, 2016). The shuttle ran Monday through Saturday. The design of the shuttle did not allow for ADA accessibility. At the conclusion of the pilot testing demonstration, approximately 15,000 passengers were transported. Surveys of riders, cyclists, pedestrians, the general public, and local stakeholder were conducted. At the time of this report, the survey analysis has/has not been published.

Figure 3 LaRochelle shuttle route

Lausanne

The pilot program in Lausanne, Switzerland began in April 2015 (Table 3). Six shuttles serviced last-mile trips on the École Polytechnique fédérale de Lausanne (EPFL) campus (Figure 4). The shuttles are ADA accessible and could accommodate nine passengers. The maximum travel speed was 9.3 miles per hour. The shuttles ran Monday through Friday from 7:45 am to 10:00 pm with six stops.

Figure 4 Lausanne shuttle route

Figure 5 Lausanne on-demand app and shuttle
Source: CityMobil2 Newsletter, 2015, Lausanne Demonstrations: Conclusion

While Switzerland’s legislation required the presence of an onboard operator, the system also included an off-site operator. The off-site operator allowed the Lausanne system to include fleet management services provided by Bestmile. Bestmile developed a software platform for managing, scheduling, and operating the fleet of shuttle. Bestmile was an EPFL start-up business that was started in February 2014. The fleet management component allowed an operator in a remote control room to monitor the entire fleet. From the central remote control room, an operator could intervene when the shuttles stopped driving due to encounters with obstacles such as delivery trucks, construction, and poorly parked vehicles. From July 2015 to August 2015, two shuttles were operated on-demand through a smartphone app. Nearly 7,000 people experienced the Lausanne autonomous shuttle with almost 1,000 of those riders utilizing service with the on-demand app (Figure 5). EPFL Vice-President, Andre Schneider, credits the success of the Lausanne system to Easymile, which “implemented the software and robust procedures,” to Bestmile, who was “an organized and responsive operator,” and to the onboard operators (Schneider, 2015).

Oristano

From July 2014 to September 2014, the Oristano system operated two shuttles along a 0.81-mile beachfront route (Figure 6). Cyclists and pedestrians shared the boulevard route with the shuttles. There were no lane markings or barriers on the route. The Oristano system ran the shuttles in two four-hour shifts each day. Riders of the Oristano system filled out forms to register as ‘experimenters’ before boarding the shuttles. The system was reportedly well received by the public, but primarily by the elderly who used the shuttles regularly for their shopping trips (Mercier-HandiSyde, 2015). Over the course of the pilot program, nearly 2,600 passengers rode the shuttles, averaging approximately 369 riders a week (Table 3).

The organizers of the Oristano system felt the pilot program was successful because the system was integrated with minimal infrastructure changes and received positive acceptance and responses from the public. There were no conflicts or incidents reported between the shuttles and other road users. Additionally, the organizers were pleased to report that there were no acts of vandalism or damages inflicted on the shuttles (Mercier-HandiSyde, 2015). However, some technical issues were reported. The shuttles occasionally lost GPS signals when passing under big trees or thick tree canopies. These technical issues resulted in the shuttles stopping and had to convert to manual mode until the signal was recaptured.

Figure 6 Oristano shuttle route

San Sebastian

San Sebastian is the location of CityMobil2's last pilot program. The San Sebastian system operated in a technology park. The technology park is comprised of approximately 92 companies, over 4,000 commuting workers, and attracts approximately 300,000 visitors a year. With three shuttles, the system began transporting people in April 2016. The route was approximately 0.75 miles long with six stops and ran Monday through Friday (Figure 7). During the 12-week pilot program, the shuttles transported over 2,500 passengers and reported no incidents (Mercier-Handisyde, 2016).

Figure 7 San Sebastian shuttle route

Sophia Antipolis

The Sophia Antipolis systems deployed four shuttles in February 2016. The system featured five stops at various shops, restaurants, and businesses (Figure 8). Three shuttles were in operation during peak hours. The shuttles ran on a 0.93 mile segregated lane that was shared by cyclists and pedestrians (Table 6). After the pilot program, the shuttle lane was converted into a bicycle track.

Figure 8 Sophia Antipolis shuttle route

Set-up and testing for the pilot program occurred from December 2015 to January 2016. Set-up for the pilot program included construction of stations at the shuttle stops with ADA accessibility, route resurfacing, and road markings (Figure 9). Also included in the set-up was the installation of stop signs, which gave priority to the shuttles, totem information, beach flag, and welcome/information tents. Posters and totems were installed along the route to educate the public about the pilot program. The welcome/information tents were set-up at the end of the route to provide information for passengers.

Figure 9 Sophia Antipolis route infrastructure before (top) and after (bottom)

Source: CityMobil2 Sophia Antipolis Demonstration, 2017, Results and Lessons Learnt

Trikala

Automated shuttle testing for Trikala occurred from November 2015 to February 2016. The shuttle operated a 1.55-mile route linking a city center with a central business district (Figure 10). Infrastructure changes were made in preparation for shuttle deployment (Raptis, 2016). Trikala constructed a dedicated asphalt lane and a control center along with technical modifications to traffic lights. As seen in Figure 11, the Trikala system installed road stud or cat's eye infrastructure to segregate the shuttle lane from the rest of traffic. Seventy on-street parking spaces were removed to allow the shuttles to operate in the newly constructed lane. Once the program received its six shuttles, the pilot conducted initial testing of the shuttles and mapping of the route with no passengers aboard. The Trikala shuttles were designed with ADA accessibility, featured an emergency stop button, and had a shuttle capacity of ten passengers.

According to a law in Greece, the vehicle controller, whether onboard or off-site, is responsible for the shuttle (Papastergiou, 2016). There was no law requiring an onboard operator, so the program chose to use both an onboard and off-site operator. From November 2015 to January 2016, the shuttles transported people with an onboard operator. In February 2016, the shuttle transported passengers with no onboard operator but with an operator in a remote control room instead. The off-site operator used cameras that allowed them to monitor and intervene in the systems operations when necessary (Mercier-Handisyde, 2016).

Figure 10 Trikala shuttle route

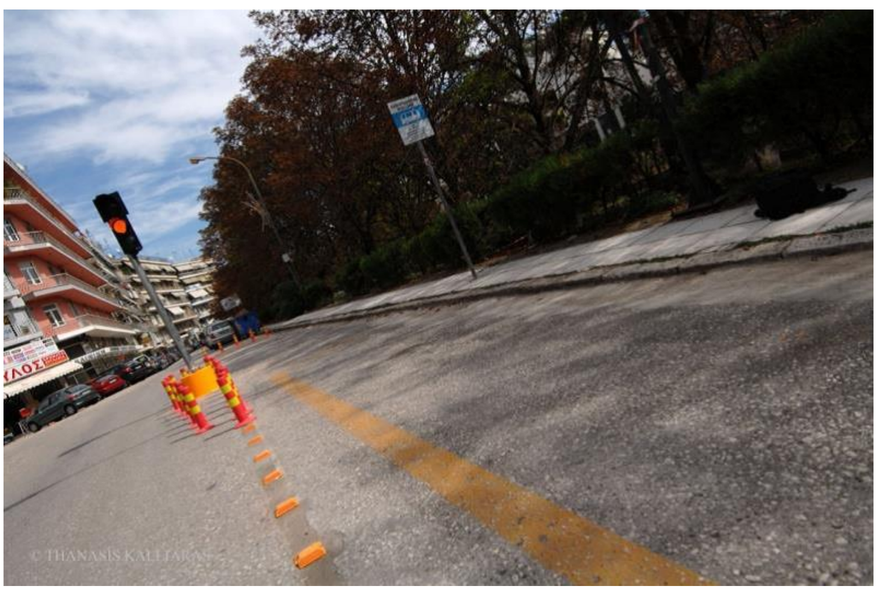


Figure 11 Road studs on Trikala shuttle route
Source: CityMobil2, 2016, Final Conference, San Sebastian, Spain

Vantaa

The Vantaa pilot program was in operation from July 2015 to August 2015. The Vantaa system transported people from the new Kivistö Railway Station to an exhibition area where the annual 2015 Housing Fair was held (Figure 12). The Housing Fair attracts 100,000 to 200,000 visitors a year. The Vantaa system offered a nonstop service on a 0.53 mile fully segregated and fenced lane (Figure 13). Just over 19,000 passengers rode the shuttle during the four-week pilot program.

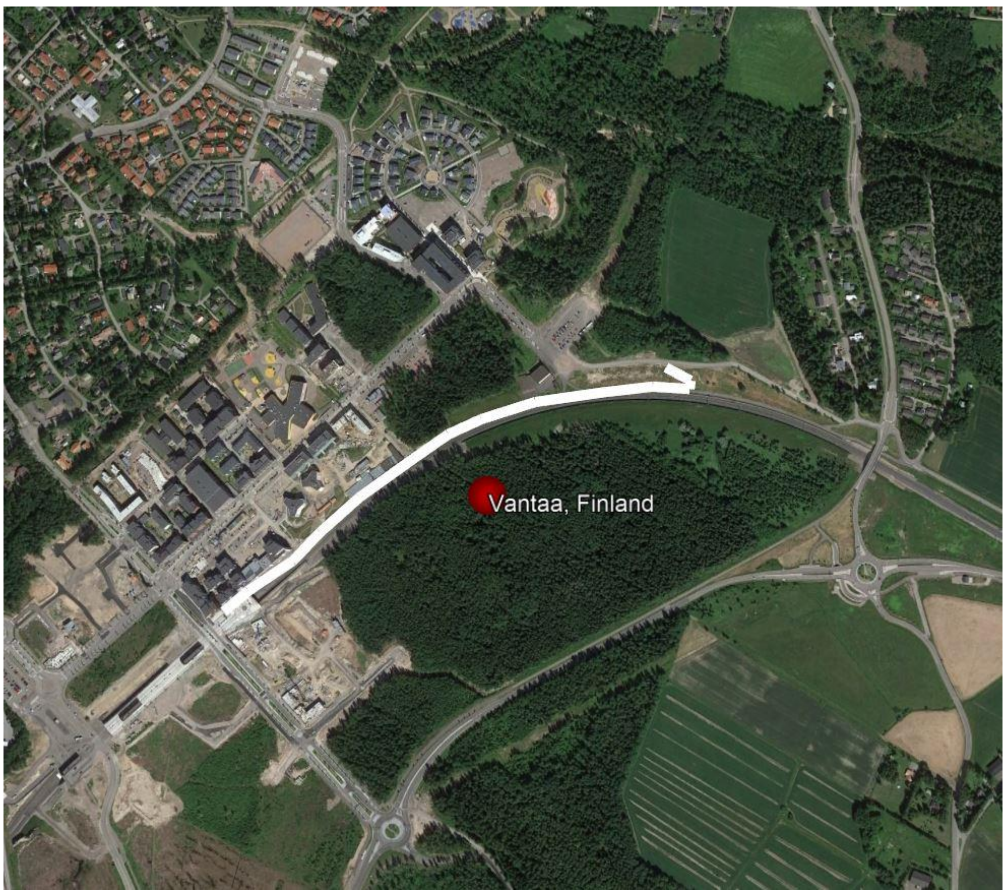


Figure 12 Vantaa shuttle route

Figure 13 Vantaa fenced segregated shuttle route
Source: CityMobil2, 2016, Final Conference

Province of Gelderland

WEpods is a project initiated by the Province of Gelderland. The Province collaborated with the Technical University of Delft (TU Delft), asking them to create a proof of concept (Van der Wiel, Automated Shuttles on Public Roads: Lessons Learned, 2017). The project also included collaborations with Robot Care Systems, Spring Innovation Management, Connekt, and Mapscape. The project was initially scheduled for just one phase lasting approximately one and a half years. The project has since evolved into a new three-phase pilot program with an expected end date of 2019. This report will only cover the specifics of phase one since it has been completed by the predetermined completion date.

Phase one of the project was located in Wageningen, Netherlands and ran from March 2015 through March 2017. The project purchased two EZ10 shuttles and equipped them with additional systems, like environmental sensors so that the shuttles could handle operating in the mixed traffic of public roads (Van der Wiel, 2017). After engineering and equipping the shuttles, the program officially launched its testing phase in January 2016. During the testing phase, the pilot program was allowed to operate on public roads but not with passengers. Testing the shuttles without passengers was a precaution taken because of the systems' software, and functionality required validation. Testing was conducted on secluded roads during off-peak hours. During the testing phase, onboard operators monitored the operation and stopped the shuttle in anticipation of all approaching road users. This process continued until the project felt confident "that the navigation systems were reliable enough not to take an unexpected departure" when approached by other road users (Van der Wiel, 2017).

The project had two prerequisites for shuttle deployment. One prerequisite required that existing infrastructure remain unchanged but with one exception. The project required that any busy crossings the shuttles would encounter be equipped with traffic lights that use WIFI-P to communicate with the shuttles. The second prerequisite required that an onboard operator be present in the shuttle during operation. With the prerequisites established, in June 2016, the project received permission to begin testing the pilot program with passengers on the Wageningen Campus. In December 2016, the shuttle route was extended to the rail station in the City of Ede.The shuttles ran on a route of approximately 4.97 miles (Figure 14). The shuttle only ran on Tuesdays from 11:00 am to 1:00 pm.

Figure 14 Wageningen shuttle route

Municipality of Appelscha

The Municipality of Appelscha conducted an autonomous shuttle pilot program in Appelscha Village. The municipality completed an evaluation report about the pilot program in 2016, located on their website. The pilot program intent was to address the transport problem of the rural community, explore the elements necessary to implement an autonomous shuttle and establish the municipality as a place of innovation (Municipality of Ooststellingwerf , 2017). The municipality received approximately $167,000 of funding from the Mayor and Alderman of Appelscha. The funding covered the rental of two Easymile shuttles, public relations, infrastructure, traffic controllers, and other miscellaneous charges such as insurance, meeting room rentals, and cameras. See Table 4 for cost breakdown. The pilot program ran from September 2016 to November 2016 with shuttle service between 9:00 am and 6:00 pm. The shuttle operated on a two-way bike path connecting the Wester Es to the National Park Drents-Friese Wold (Figure 15). The bike path route was pre-programmed for the Easymile shuttle and was approximately 1.6 miles. Appelscha made adjustments to the route and the shuttle. For the route, warning signs and matrix boards were placed at various locations, low-hanging branches were trimmed, and a berm was mowed regularly to prevent the shuttle from detecting obstacles that would cause it to unnecessarily stop (Boersma, 2017). Modifications to the shuttle include allowing the door to be opened from the inside and outside and removal of sharp edges. The municipality was required to have a steward onboard at all times.

Figure 15 Appelscha shuttle route

Table 4 Appelscha financial summary for pilot program

Line Item	Cost
Infrastructural Measures: Changes in route, signage, pruning trees, mowing verges, drips, cleaning up measures	$35,714
Publicity – Communication: Promotional material, video, opening etc.	$13,400
Rent Miscellaneous: (including easy mile) Easymile (two vehicles, balancing, training, etc.) and rent two tents for storage	$73,053
Traffic Controllers: Use traffic controllers for informing other road users	$30,571
Miscellaneous: RDW, insurance, cameras, fire extinguishers, installation loading, rent meeting rooms, small material.	$13,370
Total:	$166,108

Source: Township Ooststellingwerf, 2017, Evaluation Report

Chapter 5 - Pilot Program Elements

This chapter is one of two main components that establish the elements necessary for implementing an autonomous shuttle pilot program. There are three categories of elements: site selection, program design, and partnerships. Site selection refers to transit agencies defining the purpose of their program and understanding how the shuttle's operational environment affects the system. Program design focuses on the influences of shuttle services and operations. Partnerships refer to the type and benefits of collaboration needed to deploy a pilot program. These three elements will provide transit agencies with the information they need to make informed decisions about the design of their pilot programs. The following section will break down the three elements and help transit agencies understand the different approaches by synthesizing other systems.

Element One – Site Selection

This report identifies site selection as the first elemental framework for transit agencies. The site selection of a pilot program influences who has access to the system, what access the system gives to passengers, the infrastructure requirements, and how shuttles operate within its environment. The following sub-sections will expand on how the project purpose, operational environment, and right-of-way vary with different site selections.

Project Purpose & Operational Environment

It is essential to establish the purpose of a pilot program because it dictates the design and guides stakeholders to potential partnerships. This section will analyze how the intent of a project relates to the operational environment of pilot programs.

The pilot programs were implemented in four different environments (Table 5). The LaRochelle, Trikala, and Wageningen systems were operational in city centers, the Sophia Antipolis, San Sebastian systems were operational in working districts, the Lausanne system was operational in an educational district, and the Oristano, Appelscha, and Vantaa systems were operating in recreational districts (Mercier-Handisyde, 2016). Deploying pilot programs in a variety of environments allowed the project to test and validate systems and services that could not be obtained at one location.

Table 5 Operational environments for pilot program systems

System Location	Operational Environment
Appelscha	Recreational District
LaRochelle	City Center
Lausanne	Educational District
Oristano	Recreational District
San Sebastian	Working District
Sophia Antipolis	Working District
Trikala	City Center
Vantaa	Recreational District
Wageningen	City Center

The Sophia Antipolis system operates in a working district environment. The purpose of the Sophia Antipolis pilot program was to complement existing transit systems and serve as a first mile last mile solution. An automated shuttle provides the area with an innovative means of transportation and connects a bus stop to shops, restaurants, and jobs (Mercier-Handisyde, 2016).

The San Sebastian system operated in a science park also referred to as a working district. This environment was selected for a pilot program because it combined real traffic conditions with relatively low traffic intensity (Mercier-HandiSyde, 2016). Every year the park attracts 300,000 visitors from around the world, and a reported 67% of people accessing the science park were car users. The San Sebastian system offered the last mile transport option where no transportation service ever existed (Mercier-HandiSyde, 2016). The site in which the San Sebastian system operates in features museums, parks, and shopping. With the addition of those features, the operational environment can be considered a combination of a working district and recreational district. Selecting a site that can be categorized as two operational environments offer transit agencies an added benefit. A site with multiple environments will likely increase the number of people who are exposed to the system because the site will have a variety of services and options that appeal to more people. Selecting a site that has multiple environments is an excellent choice for transit agencies that want to achieve higher ridership numbers. With higher ridership, transit agencies will have a larger pool to survey for feedback about the system.

The primary intent of the Wageningen system was to dedicate their limited resources to validating the engineering applications of an automated shuttle in an urban setting and accelerate market development (Van der Wiel, 2018). This pilot was not focused on transport capacity, minimum trip time, or uptime. At the request of the Province of Gelderland, the pilot program was to illustrate the technical capabilities of an automated shuttle. The decision to conduct a pilot program with no concern about ridership allowed the program to reduce its number of stops and increase travel speed; those decisions came at the cost of reducing access to the public. The Wageningen system offered a non-stop transport option by connecting a transit station with a university.

The Appelscha pilot program had several objectives: 1) Highlight the transport problems of rural communities, 2) investigate the capabilities of automated vehicles when transporting passengers on public roads, and 3) put Appelscha on the map as a recreational and innovative municipality (Township Ooststellingwerf, 2017). With their purpose defined, the Appelscha system operated in a recreational district and provided a non-stop shuttle service transporting passengers from the Appelscha Village to a visitor center approximately 2 miles away. One potential tradeoff of a recreational environment with a nonstop service is reduced exposure. People have varying interest in a variety of recreational activities and some recreations will not appeal to everyone. If a transit agency selects a recreational environment with a nonstop service then the agency should give extra consideration to the origins and destinations selected if they want to maintain appeal to as many people as possible.

Right-of-Way

Table 6 identifies the right-of-way for the pilot program systems. Right-of-ways refer to the right to move onto or across a road before other people or vehicles (Merriam-Webster Incorporated, 2018). This report identifies three types of shuttle system right-of-ways and are categorized as: segregated, dedicated, and shared (Figure 16). Segregated traffic is a lane separated from vehicular traffic but may be accessible to pedestrians and cyclists and is utilized by the shuttle. Dedicated traffic is an allocated lane with defined markings to illustrate shuttle use and is directly next to lanes used by other road users such as vehicles, cyclists, and pedestrians. Shared traffic is a lane that can be used concurrently with other road users such as vehicles, cyclists, and pedestrians and may or may not have defined lane markings indicating shuttle use.

The Appelscha system was the only pilot program examined that operated on a segregated two-way bike path. Easymile was responsible for the risks analysis of the area and selected the bike path for the pilot (Boersma, 2017). The right-of-way allocated for the Appelscha system seemed to be suitable for the pilot because the route made a recreational connection that would have transport demand and the speed difference between the shuttle and cyclists was minimal. However, the width of the shuttle and width of the route was not optimal in that it left only two feet to three and a half feet for cyclists. Adjustments were required to maintain the intent of the project and public safety. See sub-section "Operational Challenges" for more information about the shuttle/cyclist conflict.

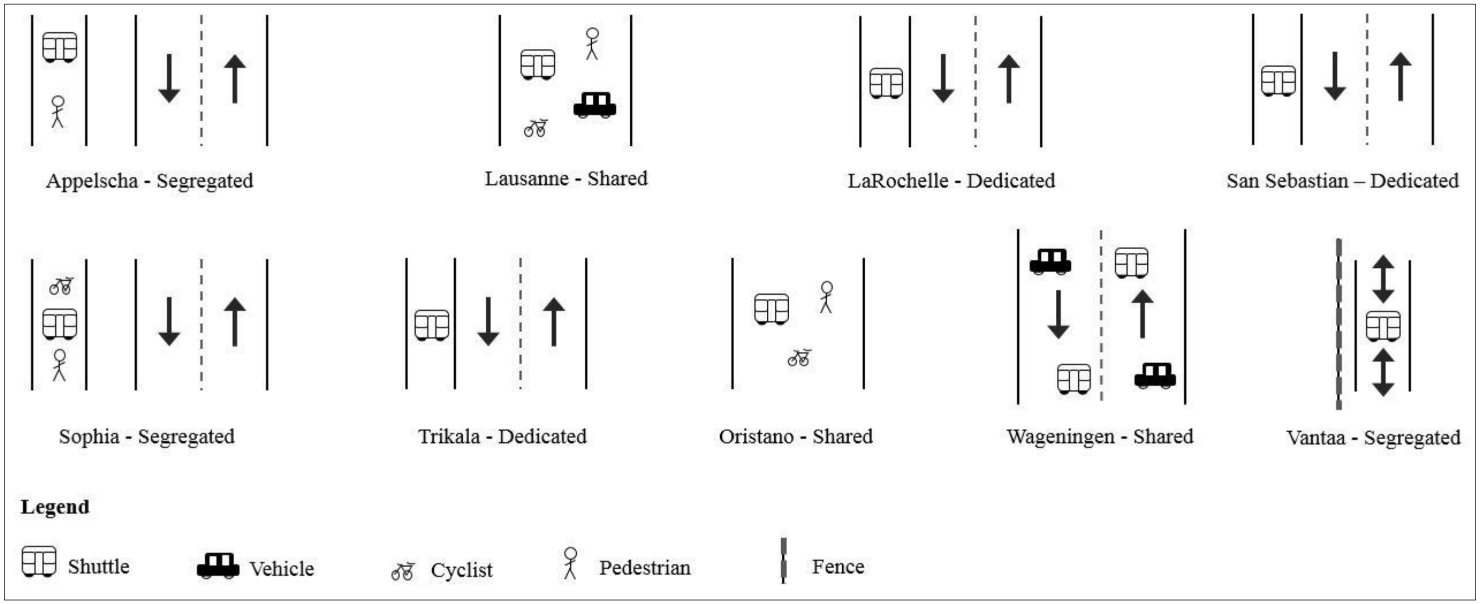


Figure 16 Shuttle systems road diagram

Table 6 Shuttle systems right-of-way

System Location	Right-Of-Way		
	Segregated	Dedicated	Shared
Appelscha	two-way bike path		
LaRochelle		allocated lane	
Lausanne			cyclist, pedestrian, vehicle path
Oristano			cyclist, pedestrian path
San Sebastian		allocated lane	
Sophia Antipolis	cyclist, pedestrian path		
Trikala		allocated lane	
Vantaa	fenced lane		
Wageningen		cyclist, pedestrian, vehicle lane	

Since the Trikala system operated in a city center district, the right-of-way required the construction of a dedicated lane, which in turn required the removal of 70 off-street parking spaces. Similarly, the LaRochelle system operated in a city district and required the removal of off-street parking. For transit agencies that select a city center as the operational environment for the pilot program, a shared lane right-of-way is not recommended. City centers are the location of commercial businesses. Commercial businesses attract shoppers and workers thus increasing traffic. Automated and autonomous shuttles sense its surroundings for navigation so environments that generate many trips will create more complex scenarios for shuttles. To reduce conflicts between the shuttle and other road users, transit agencies should at least create a dedicated lane for the shuttles with ample lane markings and signs. After Trikala implemented their pilot program, they recommend that future automated shuttle applications located in urban environments should use segregated lanes because "it gives the impression of a standalone system" (Raptis, 2016). A segregated lane will increase awareness and improve safety.

The Oristano pilot program had initial concerns over its site selection and right-of-way for its shuttle system. The concern was that other road users, such as pedestrians and cyclists, would try testing the capabilities of the shuttles' sensors by jumping in front of the shuttle (Mercier-HandiSyde, 2015). While the Oristano program reported no issues with people testing the system, the San Sebastian program did encounter "several un-civic behaviors" from other road users (CityMobil2, 2016). However, no further details about the type and frequency of the behaviors were provided. For transit agencies testing their systems on private property, stunting activities like the ones reported in San Sebastian should be less of a problem. A pilot program that operates on private property will likely, transport and interact with the same passengers and road users every day. For example, if testing shuttles within a working district, or office park, those that interact with the shuttle will be the employees and staff to the business within that park. The site selected for the San Sebastian pilot program provided service not only for the thousands of workers that commuted daily but also for the 300,000 visitors attracted to the site for the culinary center, hospital, and retirement home. Although the San Sebastian system operated in a working district, one could conclude that what contributed to the 'un-civic behaviors' were those who visited the site for personal rather than professional reasons. Planning for the type of users, of an automated shuttle, is important for transit agencies to understand when considering site selection.

Eight of the nine pilot programs examined in this report operated on public streets. The Lausanne system was the only pilot program examined in this report that operated on private property. EPFL is a public educational institution owned by the Swiss Confederation yet built on private property (Mercier-Handisyde, 2015). Some transit agencies in the United States will have to operate a pilot program on private streets. Transit agencies located in states where autonomous vehicle testing is not allowed on public roads will have to test a shuttle on private property. Testing an autonomous shuttle on private streets has its benefits such as offering a higher level of control of the environment and the shuttle passengers. In addition, transit agencies may be able to avoid some of the legislative constraints and requirements that pilot programs in Europe had to mitigate.

Element Two – Program Design

Shuttle Service & Operation

All CityMobil2 pilot programs had a human operator in the shuttle because of legal and operational requirements (CityMobile2, 2016). WEpod's Wageningen pilot program had both an onboard operator and off-site operator. For the implementation of the Wageningen pilot program, an onboard operator was required, but recent proposals seek to allow automated shuttles to operate without an onboard operator (Van der Wiel, 2017). In the Wageningen system, the off-site operator worked in a control room where he/she monitored the shuttle with the assistance of three onboard cameras. The off-site operator was not in control of the shuttle during operation but was alerted when there were issues. The off-site operator was not allowed to facilitate control of the shuttle but merely instruct orders for the shuttle to execute (Van der Wiel, 2017).

All nine pilot programs set the maximum operational speed of the shuttle below the shuttles actual maximum speed capability. The EZ10 shuttle is capable of operating at a maximum of 27.9 mph. One of the reasons for setting a lower maximum speed was because autonomous vehicles are complex and its safety and efficiency are still unknown; the pilot programs established a maximum speed below its maximum capability (Table 7). The Wageningen pilot program had the highest maximum speed during testing. The Wageningen system's maximum speed was set slightly below the posted speed limit for the cars in the area. The Appelscha system's maximum speed was set comparable to the speed of cyclists. The Wageningen system and the Appelscha system both set the maximum speeds of their shuttles comparable to the types of mode of transportation they would interact with, yet the Appelscha system caused frustration for cyclists. Because the speed of the shuttle was comparable to the speed of a cyclist, the cyclists found in difficult to determine whether they could pass the shuttle (Boersma, 2017). The issue the Appelscha system had was because it tried to match a vehicle (shuttle) speed with the speed of cyclists whereas the Wageningen system chose to match the vehicle (shuttle) speed with vehicle speed. Just because the shuttle speed is matched with cyclists speed, it does not automatically eliminate conflicts and issues between the two. Transit agencies need to evaluate and design their automated shuttle system based on the site selection and right-of-way to minimize conflicts and issues the shuttle will encounter with other road users.

Table 7 Shuttle systems operations and services

System Location	Operations		Service		
	Operator Type	**Max. Speed During Program** (mph)	**ADA Accessibility**	**Days of the Week**	**Hours of the Day**
Appelscha	Onboard	9.3	Yes	n/a	9:00 am – 6:00 pm
LaRochelle	Onboard	6.2	No	Mon. – Sat.	n/a
Lausanne	Onboard & Off-site	9.3	Yes	Mon. – Fri.	7:45 am – 10:00 pm
Oristano	Onboard	n/a	n/a	Mon. – Sat.	n/a
San Sebastian	Onboard	n/a	n/a	Mon. – Fri.	n/a
Sophia Antipolis	Onboard	8.1	Yes	Mon. – Fri.	8:00 am – 6:30 pm
Trikala	Onboard & Off-site	n/a	Yes	n/a	n/a
Vantaa	Onboard	8.1	n/a	n/a	n/a
Wageningen	Onboard & Off-site	15.5	Yes	Tuesday	11:00 am – 1:00 pm

Table 8 Shuttle system connections

System Location	Origin	Destination		# of Stops
		Transit	Site	
Appelscha	Appelscha Village		Staatsbosbeheer Visitor Center	2
LaRochelle	University	Metro Station		6
Lausanne	Campus Innovation Park	Metro Station		5
Oristano	Torregrande Village		Promenade	5
San Sebastian	Technology Park		Technology Park	6
Sophia Antipolis	Science Park	Metro Station		5
Trikala	City Center		Central Business District	6
Vantaa	Exhibition Center	Metro Station		2
Wageningen	University	Metro Station		2

Connections

Connections are a part of the system operations that provide people access to destinations. The connection of an autonomous shuttle pilot program system reinforces the intent of the project. Transit agencies that want a high-profile pilot program where it will attract riders should consider a system that connects to a site that generates a large number of trips and. The system should also have multiple stops at popular locations between the origin and destination. The three systems with the highest ridership numbers are the Vantaa, LaRochelle, and Trikala systems. Of those three systems, the Vantaa and LaRochelle systems connected to metro transit stations. However, the Vantaa system only had two stops in its connection while LaRochelle had six stops (Table 8). Comparing these two systems shows that the same project intent can be reached with different connection choices. For the Vantaa system, a nonstop connection to a Housing Fair, which attracts over 100,000 people a year, is a sufficient program design for achieving high ridership numbers. The LaRochelle system connected a transit metro station with an educational university and incorporated four additional stops through a business district. With the additional stops, the LaRochelle system can garner more public interest because the additional stops add convenient access. The LaRochelle system and the Vantaa system are two examples of achieving the same goal through different means.

Table 9 Comparison of systems connected to educational districts

System Location	Total # of Riders	Pilot Program Duration	Connection to Educational Institution	Enrollment	
				Students	Staff & Faculty
LaRochelle, France	14,660	18 weeks	University of LaRochelle	8,595	n/a
Lausanne, Switzerland	7,000	19 weeks	EPFL – Campus Innovation Park	14,475	3,325
Wageningen, Netherlands	1,000	39 weeks	Wageningen University	11,275	3,585

Three pilot programs connect an educational institution to a metro transit station (Table 9). Of the three systems, the Lausanne system is the only one considered to operate in an educational district, whereas the LaRochelle and Wageningen systems operate in city centers. An automated shuttle connection to an educational district will offer a wide range of potential passengers (CityMobil2, 2016). If it is the intent of a transit agency to obtain high ridership numbers and increase public awareness, connecting the system to an educational institution is a good option. Ecole Polytechnique fédérale de Lausanne (EPFL) is the campus innovation park in Lausanne, Switzerland. The LaRochelle pilot program had at least twice as many riders than the Lausanne pilot program. Not only did LaRochelle have twice as many riders, but it also had one less stop and lasted four weeks shorter than Lausanne. The difference in ridership numbers is attributed to the location of the stops. While LaRochelle connects an educational institution to a transit station, the intermediate stops include tourist/attractions sites. The LaRochelle system is more accessible to university affiliates, the public, and tourists than the Lausanne system. The Lausanne system operates within EPFL, and all intermediate stops are located on the campus. The spacing of the stations was set far enough apart to ensure efficient route times and avoid competing with walking (CityMobil2, 2016). This research recommends that for a more controlled environment and audience; locate a pilot program system and it stops within a single land use such as universities, office parks, and airports. Table 6 shows the right-of-way allocated for each pilot program, which suggests that initial testing of an autonomous shuttle occur in a semi-controlled environment.

Element Three – Partnerships

An autonomous shuttle pilot program is a complex project that requires research, development and engineering, investment, and management. Stakeholders contribute to projects by providing knowledge and experience beyond a transit agencies capability. By diversifying the stakeholder partnerships, transit agencies have the best opportunity to deploy a safe, reliable, efficient, and innovative pilot program. Cooperation between different stakeholders supports the progress of a project (Dall'Oglio, et al., 2016). Dall'Oglio, et al. organizes stakeholders into two groups: traditional transportation stakeholders and emerging and prospective transportation stakeholders. A traditional transportation stakeholder is a business already established in the transportation sector such as a transit agency, vehicle manufacturer, departments of transportation, and insurance companies. An emerging and prospective transportation stakeholder is business that seeks to exploit and advance their area of expertise in the emerging technology such as technology companies and providers of transport mobility services (i.e., Uber). This report has organized the pilot program partnerships into four categories: municipalities, educational and research institutions, public sector organizations and operators, and private sector and consultants.

The CityMobil2 project collaborated with over 45 partners ranging from cities, research organizations, private consultants, and software developers (Table 10). CityMobil2 (2016) states that one of the key strengths to the success of the pilot programs was the cooperation and partnership with municipalities. The WEpods project also found their partnerships to have played a role in their automated shuttle implementation. “All stakeholders were involved from the start, including relevant authorities. The project became “a true triple helix cooperation; that proved to be crucial to its success” (Van der Wiel, 2017). Policy initiatives affect autonomous vehicle implementation by influencing the timing of deployment, impacting the progressional development of the technology, and hindering potential benefits for public transportation and society (Polzin, 2016). The development of laws and regulation for autonomous vehicles are still ongoing worldwide; they are not sufficient, fully developed, or simply do not exist at all. The safety and reliability of autonomous vehicles have yet to be fully realized. Not knowing the ultimate effects of autonomous vehicles makes knowing how to regulate them difficult for municipalities so for transit agencies, having partnerships with them is beneficial and necessary especially for operating on public roads. All the pilot programs examined in this report had partnerships with a municipality, and without those partnerships, autonomous shuttle deployments would have suppressed or cease to exist because legislative adjustments and approval were required to operate on public roads. Not only can municipalities help further the initiatives of autonomous vehicle implementation, they too can benefit.

Table 10 Shuttle systems partnerships

System Location	Municipality	Educational & Research Institution	Public Sector Organizations & Operator	Private Sector Companies & Consultants
Appelscha	8	8	9	3
LaRochelle	10	13	5	15
Lausanne				
Oristano				
San Sebastian				
Sophia Antipolis				
Trikala				
Vantaa				
Municipality of Appelscha				
Wageningen	5	3	0	9

Municipalities can have a vested interest in the deployment of autonomous shuttles. Cities have the power to direct investment from the private sectors towards assets that support autonomous vehicle implementation (Bits and Atoms, 2017). The application of autonomous shuttles in public transportation is an innovative initiative for transit agencies and municipalities and will garner worldwide attention. One of Appelscha's pilot program objectives was to "put Appelscha and the municipality of Appelscha on the map as a recreational area and innovative municipality" (Township Ooststellingwerf, 2017). Municipalities and transit agencies looking to establish or maintain a competitive edge will undoubtedly receive interest from investors, in the public and private sector as well as from educational and research institutions.

Educational and research institution stakeholders make for an ideal partnership. Academia assists in research and development by creating prototypes and mobility systems, and they collaborate seamlessly with public and private stakeholders (Dall'Oglio, et al., 2016). Educational institutions are built on innovation and can provide transit agencies with resources beyond those of municipalities, public sector, and private sector stakeholders. The Technical University of Delft (TU Delft) provided the Providence of Gelderland with a proof of concept for automated shuttles in public transportation. TU Delft gave Gelderland access to resources and expertise that they were lacking.

Chapter 6 - Considerations & Best Practices

This chapter is the second main component of this report. It highlights essential considerations and recommends best practices for transit agencies. This report has identified four considerations, which included: cooperation, evaluation, phasing, and pilot program configuration. Cooperation refers to the importance of defining and understating roles and responsibilities of key personnel and partners. Evaluation refers to how transit agencies can assess the system and its influence on the public. Phasing refers to the systematic approach for deploying an autonomous shuttle pilot program. The final consideration is pilot program configuration, which provides transit agencies insight on how speed and infrastructure can influence the system.

Considerations

Consideration One – Cooperation

Cooperation is about teamwork and coordination among stakeholders and partners. It would be in the best interest of transit agencies to define roles and responsibilities early on in the planning process of an autonomous shuttle pilot program. Transit agencies will want to have an explicit understanding of expectations from all stakeholders because it will help streamline deployment and ensure that day-to-day operations are safe, efficient, and reliable. CityMobil2 (2016) acknowledges that cooperation with the shuttle manufacturer is "essential" and that binding contracts on who is responsible for service operation be established. CityMobil2 also recommends that the designated project coordinator, who is responsible for the systems operations and performance be accountable to the city. This recommendation is an important consideration for transit agencies that test on public roads because a city has an obligation to protect the health, safety, and welfare of the community. By requiring that the project coordinator be responsible to the city, a transit agency can ensure that the pilot program is compliant, thus allowing for smoother operations. For stakeholders and partners that do not have specific responsibilities in the deployment and operation of the shuttles, they should be kept well-informed (Van der Wiel, 2017).

The Appelscha pilot program reported difficulty with communications with the shuttle manufactures and caused unplanned delays. For transit agencies, delays in the project can strain the budget and diminish the program design. The shuttle manufacturer played a vital role for Appelscha because they provided the shuttles, technology, and training. If cooperation among stakeholders is not reliable, issues will arise.

One of the lessons learned in the Wageningen pilot program was how to mitigate problems they could have never expected. Wageningen dealt with technical, organizational, legislative, and judicial problems as well are cooperation and public relations issues (Van der Wiel, 2017).

Consideration Two – Evaluation

This report was created out of a need for a comparative analysis that helps transit agencies make informed decisions; it is essential for those conducting pilot programs to evaluate and maintain qualitative and quantitative reports regularly. Maintain thorough and well-organized information because “various pilot projects, demonstration projects, and early deployments provide learning opportunities for individual agencies that can be shared with the industry, create a positive progressive appearance for public transportation, and create an opportunity for technology to benefit the industry and its customers” (Polzin, 2016). One of the criteria used in this report for selecting which pilot programs to examine was available information. There are several pilot programs around the world that have occurred and there are several planned for future deployment. An Easymile Sales Director commented that the company is currently in partnership with several pilot programs in the United States but that some of them wish to remain anonymous (Joseph, 2018). The application of autonomous shuttle in public transportation will affect society, accessibility, partnerships, business cases, and transit operations. When an innovation such as an autonomous shuttle can have an impact on a variety of public and private operations, it is important to provide other transit agencies with the knowledge that is gained through pilot programs. Transit agencies need to understand how influential their pilot program will play in future pilot programs and applications.

Consideration Three – Phasing

Much like the framework elements, phasing for a pilot program is dependent on the project purpose. If a project is aimed at providing an alternative mode of transportation in a city center then it may require more testing of its software and operational capabilities before transporting passengers because of the complex environment. The more scenarios possible in an operational environment, the more operational challenges the shuttle system will face. Also, a city center environment is more congested, and safety for the people will be a very high priority. This researcher recommends that transit agencies allow for longer testing phases, so the shuttle systems are more prepare for the complex scenarios and environments. Regardless of the pilot program purpose or the operational environment, transit agencies should expect and plan for delays (Township Ooststellingwerf, 2017). Orchestrating a project will bring about issues and questions that could not be expected since an autonomous shuttle pilot program is not typical.

Conduct short demonstrations on public roads, if allowed, to introduce an automated or autonomous shuttle to the public. A short demonstration will attract public attention and increase user support. Additionally, short demonstrations will offer new testing environments that are necessary for data collection, for gaining experience and for validating the technology (Lohmann & Van der Zwaan, 2017). The pilot programs examined in this report exercised precautions when they implemented an automated shuttle. Examples of precautions taking in the pilots include reduced shuttle speed, infrastructure adjustments giving priority to shuttles at busy crossings, and additional signage and road markings that indicated shuttle's presence. Transit agencies should also take similar precautions and use each testing phase as an opportunity to prove the safety and functionality of the shuttle system. Each testing phase for the shuttle could introduce different operational variables for the shuttle system. ITF (2015) suggests that pilot programs can expand its system to public streets, test at higher speeds, and operate on more road types.

Automated Trials to Autonomous Applications

When approaching an autonomous shuttle pilot program, it is important to understand that the shuttle may not, initially, operate autonomously. "AVs are not as autonomous as their inventors would like us to think" (Bits and Atoms, 2017). The autonomous shuttles used in pilot programs that this report examined did not operate fully autonomous but instead at level 4. The shuttle is capable of testing and operating fully autonomous (level 5), but for safety reasons the system is automated. An automated shuttle operates on a predefined route under the supervision of an operator onboard and/or an operator in a remote location. Automated vehicles in public transit is not a new practice (Bits and Atoms, 2017). Autonomous shuttles becoming part of a public transit system requires assurance in its safety and feasibility. Because an autonomous shuttle still requires testing, it is not suitable to operate at level 5 automation. As ITF (2015) contends, "these vehicles would not reach full automation (level 5) unless they handled all roadway and environmental conditions that can be managed by a human driver." For some pilot programs, transitioning to fully autonomous is not their main purpose. The Wageningen pilot program has no intentions of developing their systems beyond level 4 automation in later phases (Van der Wiel, 2018).

It is through pilot program testing that transit agencies can transition from automated to autonomous. Incremental testing of automated shuttles leads to incremental improvements by providing data and information (Bits and Atoms, 2017). These incremental improvements enable new product design and pave the way for the safe and reliable integration of autonomous shuttles. As reported by Lohmann & Van der Zwaan, (2017) to deploy autonomous shuttles there needs to be an understanding that it is a transition from controlled environments to uncontrolled environments.

An autonomous shuttle pilot program is considered a trial. As Lohmann & Van der Zwaan (2017) state, "trials are mainly used for experimenting, gaining experience, validating the technology, and . . . gathering and sharing data." Transit agencies interested in implementing a pilot program need to be aware that autonomous shuttles are still experimental and that their system set-up and data generated will influence the design and application of a fully autonomous shuttle in public transportation.

Operational Challenges

Weather conditions will present operational challenges for an automated/autonomous shuttle system. The summer heat wave in Lausanne required the use of an air conditioning system in the shuttle. Running the air conditioning system contributed to draining the electric battery faster thus reducing the operation run-time of a fully charged battery. TheLausanne heat wave also created more dust in the air which interfered with the shuttle's laser perception

(Pessaro, 2016). Other challenges for the Lausanne system included external factors such as improper parking, delivery vehicles, and construction activities, which make it difficult for the shuttle to maintain its pre-defined route (Mercier-Handisyde, 2015). Two collisions were reported in the Lausanne system. One collision was between two shuttles that sustained light damage to the bumper. The second incident was a collision between a shuttle and a cyclist, but the cyclist experienced no physical damage. At the time of this report, no further information was provided about the collisions.

The Oristano system reported technical issues with maintaining a GPS signal. The technical issues like a loss in GPS signals and sensors so sensitive they can detect a dandelion require complementary and parallel systems that can prevent the unnecessary and frequent stops reported in several pilot programs. As Appelscha learned, “sensors should be better adjusted so that they are less susceptible to, for example, falling leaves and rain” (Boersma, 2017).

Appelscha system faced operational challenges because of its conflict with cyclists. The system had 77 emergency stops, and the leading causes were from cyclists on the path and vegetation along the route (Township Ooststellingwerf, 2017). When cyclists got too close to the shuttle, it slowed down or made an emergency stop (Boersma, 2017). The width of the shuttle occupied the majority of bike route and in some cases forced cyclists off the route and into the road (Township Ooststellingwerf, 2017). The shuttle operated on a pre-defined route, and because of the varying width of the bike path, the shuttle was mapped to operate in the middle of the path. Given that the shuttle drove in the middle of the bike path, there remaining space on either side of the shuttle ranged from one to two feet. Because of this conflict, the Appelscha system was temporarily stopped to take additional safety measures for the cyclists (Township Ooststellingwerf, 2017). The solution Appelscha used to solve the conflict was with the addition of traffic controllers and adjusting the pre-defined route by placing the shuttle more to the right. Not only was there a conflict between the shuttle and other road users, but the Appelscha system also had operational challenges with the shuttle's sensors and the landscape. Appelscha reported the need to adjust the route again by an additional eight inches to minimize false positives (Boersma, 2017). A false positive refers to a result that shows something is present when actually nothing is present (Merriam-Webster Incorporated, 2018). Obstacles like tall grass, weeds, and low laying branches caused false positives for the shuttles system because the shuttle interpreted those obstacles as barriers on the route and would stop.

The most severe problem experienced in the Trikala pilot program was a technical issue when a shuttle veered off the road and drove up on a sidewalk (Figure 18). The shuttle's security system reacted immediately to the issue and stopped in time to miss a collision with a kiosk. Trikala Mayor Dimitris Papastergiou stated, "although the kiosk man did not find a driver to speak with, he should remember that in similar cases when 'classic' vehicles left the road, no security system prevented them from causing damage and injury" (Papastergiou, 2016). This researcher recommends that transit agencies consider that incidents similar to Trikala's could occur in their pilot program and thus reinforces the importance of extending the phasing period for shuttle and system testing.

Figure 17 Trikala shuttle drive up on a sidewalk
Source: CityMobil2, 2016, Final Conference, San Sebastian, Spain

Consideration Four – Pilot Program Configuration

Speed

This report gathered data on the maximum speed of shuttles during pilot programs on six systems. Of those six systems, the average maximum transport speed was 9.4 miles an hour (Table 7). The Wageningen system was the fastest with testing speeds at 15.5 miles per hour; they also had the longest route (4.97 miles) between all the systems examined. The Wageningen system was able to test at higher speeds because it had the minimum number of stops possible and covering a distance of nearly five miles requires faster speeds to make the trip efficient. The San Sebastian program (2016) commented that it would have benefited from increased shuttle speeds because their service could have improved its frequency. Survey results from the Sophia Antipolis pilot program indicated that 35% of passenger found the shuttle speed too slow (Drieux, 2017). However, the Wageningen pilot program states, "the biggest risk related to the automated vehicles themselves is . . . an unexpected brake action" (Van der Wiel, 2017). One of the countermeasures the Wageningen system uses is low shuttle speed. Although some passengers and system operators are not favored a low-speed shuttle, transit agencies should begin initial testing and the transporting of passengers at low speed to ensure safety remains a priority. Speed could be one of the variables that transit agencies modify in their testing phases Transit agencies can test the shuttles at increased speeds to evaluate the safety and user acceptance. If transit agencies are considering increased shuttle speed, they should consider modifying the number of shuttles in the system and the route design.

Infrastructure

The most noted infrastructure change needed for a pilot program was an increase in road markings and making them more identifiable for the shuttle and other road users. The LaRochelle system included additional infrastructure changes by using signage and road marking but noted that there was still room for improvement (Graindorge, 2016). Increasing awareness of the shuttles presence is important for the safety of the passengers and other road users. If other road users are aware they are in the presence of an automated shuttle, then they will be more mindful of their actions. In several pilot programs, additional signage was added to the routes to inform other road users that they were in the test area (Figure 18) (CityMobile2, 2016).

Figure 18 Signage added along a shuttle route
Source: CityMobil2 Newsletter, 2015, Legal Aspects Update

Best Practices

Communication

This researcher has identified communication as the best practice needed for transit agencies when implementing an automated/autonomous shuttle pilot program. This practice is especially important to transit agencies that operate in states where autonomous vehicle testing on public roads is not permitted. Implementing a pilot program can help decision makers invest in the system and take it from a trial to an application (Lohmann & Van der Zwaan, 2017). Transparent and frequent communication with decision makers helps manage expectations and opportunities. Communicating with the public is equally important. Essential preparation for implementing the public is local communication and awareness (CityMobile2, 2016). Transit agencies can inform users and manage their expectations by educating them on how the system works (Lohmann & Van der Zwaan, 2017).

Open and honest communication is crucial to gaining support an autonomous shuttle transit system. An autonomous shuttle system will have an impact on the public, which includes the shuttle rider, a person sharing the road with the shuttle, or a business owner whose store is located along the route. Before the autonomous shuttle is operational to the public, transit agencies should establish regularly scheduled public meetings that occur throughout the pilot program. The meetings should be inclusive and inform the public of the goals and intention the program. The meetings should serve as a source of education for the public and instruct them on how to interact with a shuttle and how a shuttle will respond to them. Conducting these meetings will help minimize uncertainty and promote safety (Van der Wiel, 2017). In addition to regularly scheduled meetings, transit agencies should frequently update their website, social media, and news reporters as to the progress of the pilot program. What another form of communication transit agencies needs to consider is how the shuttle communicates with its surroundings.

The EZ10 autonomous shuttle from Easymile is 100% electric and moves around quietly. A quiet shuttle does not communicate with its surroundings or people outside the shuttle. A focus group interviewed by Rodriguez (2017), suggested the use of a horn to communicate with others. A horn can warn other road users if the shuttle detects them in its path or notify them that the shuttle is approaching. In addition to other road users being able to hear a shuttle, visibility of the shuttle is as equally important.

Safety is a high priority when testing innovative technology, especially in public transportation. Pilot programs that take extra measures to ensure that other road users are aware they are in the presence of automated shuttles can reduce risks. The Appelscha system found it beneficial to make the shuttles more visible to other road users and recommends the use of reflective strips or bright, bold colors (Craen, Hoekstra, Loenis, & Schagen, 2017). For the Wageningen system to communicate with its surroundings, it chose to install ticker displays, on the front and rear of the shuttle. A ticker display is an electronic sign used to display a message or information in real-time. The Wageningen system used the default message "automated vehicle; keep distance." Since shuttles carry the risk of unexpected stops, a ticker is an extra layer of communication for road users and helps ensure safety for those on the shuttle and those interacting with it (Van der Wiel, Automated Shuttles on Public Roads: Lessons Learned, 2017). The Wageningen pilot program found it beneficial to utilize additional means of communication.

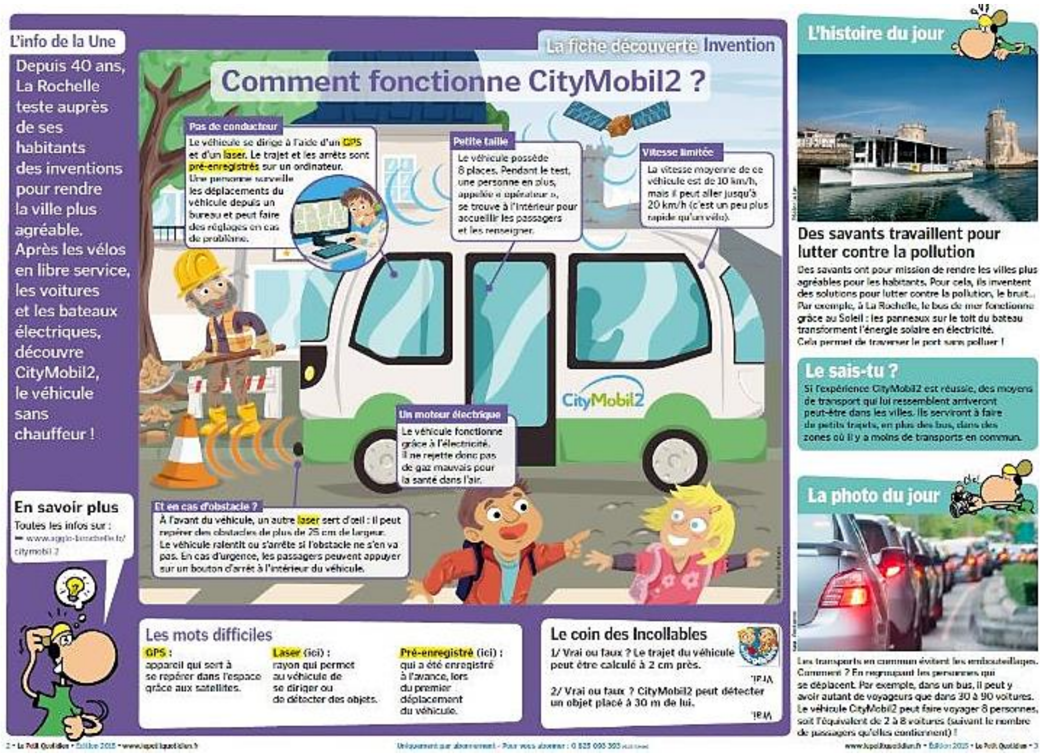
One of the challenges for the Wageningen pilot program was promoting public acceptance of the system (Van der Wiel, 2017). The program used a communication strategy that included informational meetings for the public, regularly updated information for their website and local media, and an invitation for the media to ride the shuttles. Even something as simple as the steward waving traffic on to let them know they can safely pass is a simple and effective form of communication. Maintaining a positive public attitude about the Wageningen pilot program was considered “a gate to success” (Van der Wiel, 2017).

Several systems in the CityMobil2 project targeted children in their communication strategy (Mercier-Handisyde, 2015). The La Rochelle pilot program created a special addition for the local children’s newspaper (Figure 18). As seen in Figure 19, the Oristano program also found that targeting children is a helpful communication strategy for promoting awareness and acceptance because the children often encouraged the adults to test the shuttles (Mercier-HandiSyde, 2015). Additionally, the San Sebastian program organized a drawing competition for children titled “The Bus of the Future” where the finalists and their classmates won a ride on the shuttle (Mercier-Handisyde, 2016).

The Appelscha pilot program also saw the importance of communicating with the public. The Appelscha pilot program employed traffic controllers, who served more of an informative role, were responsible for instructing cyclists on how to interact with the shuttles since their system had operational conflicts between the two (Boersma, 2017). Appelscha’s need for additional communication is a consequence of operating a shuttle on a bike path whose infrastructure was not designed to accommodate a vehicle. One source of communication used in all the pilot programs was from the onboard stewards.

The onboard stewards were an excellent source of communication for passengers and at times other road users. Trained stewards were able to answer questions and educate the passengers about the shuttle system.

Pilot programs should use a variety of communication strategies. The more thorough and varied the communication strategies are for a pilot program, the more likely the system will improve user interaction, user experience, user acceptance, and system integration.


L'info de la Une

Depuis 40 ans, La Rochelle teste auprès de ses habitants des inventions pour rendre la ville plus agréable. Après les vélos en libre service, les voitures et les bateaux électriques, découvre CityMobil2, le véhicule sans chauffeur !

La fiche découverte Invention

Comment fonctionne CityMobil2 ?

Pas de conducteur
Le véhicule se dirige à l'aide d'un GPS et d'un laser. Le trajet et les arrêts sont pré-enregistrés sur un ordinateur. Une personne surveille les déplacements du véhicule depuis un bureau et peut faire des réglages en cas de problème.

Petite taille
Le véhicule possède 8 places. Pendant le test, une personne en plus, appelée « opérateur », se trouve à l'intérieur pour accueillir les passagers et les renseigner.

Vitesse limitée
La vitesse moyenne de ce véhicule est de 10 km/h, mais il peut aller jusqu'à 20 km/h (c'est un peu plus rapide qu'un vélo).

Un moteur électrique
Le véhicule fonctionne grâce à l'électricité. Il ne rejette donc pas de gaz mauvais pour la santé dans l'air.

Et en cas d'obstacle ?
À l'avant du véhicule, un autre laser sert d'œil : il peut repérer des obstacles de plus de 25 cm de largeur. Le véhicule ralentit ou s'arrête si l'obstacle ne s'en va pas. En cas d'urgence, les passagers peuvent appuyer sur un bouton d'arrêt à l'intérieur du véhicule.

En savoir plus
Toutes les infos sur : www.agglo-larochelle.fr/citymobil2

Les mots difficiles
GPS : appareil qui sert à se repérer dans l'espace grâce aux satellites.
Laser (ici) : rayon qui permet au véhicule de se diriger ou de détecter des objets.
Pré-enregistré (ici) : qui a été enregistré à l'avance, lors du premier déplacement du véhicule.

Le coin des Incollables
1/ Vrai ou faux ? Le trajet du véhicule peut être calculé à 2 cm près.
2/ Vrai ou faux ? CityMobil2 peut détecter un objet placé à 30 m de lui.

L'histoire du jour

Des savants travaillent pour lutter contre la pollution

Des savants ont pour mission de rendre les villes plus agréables pour les habitants. Pour cela, ils inventent des solutions pour lutter contre la pollution, le bruit... Par exemple, à La Rochelle, le bus de mer fonctionne grâce au Soleil : les panneaux sur le toit du bateau transforment l'énergie solaire en électricité. Cela permet de traverser le port sans polluer !

Le sais-tu ?
Si l'expérience CityMobil2 est réussie, des moyens de transport qui lui ressemblent arriveront peut-être dans les villes. Ils serviront à faire de petits trajets, en plus des bus, dans des zones où il y a moins de transports en commun.

La photo du jour

Les transports en commun évitent les embouteillages. Comment ? En regroupant les personnes qui se déplacent. Par exemple, dans un bus, il peut y avoir autant de voyageurs que dans 30 à 90 voitures. Le véhicule CityMobil2 peut faire voyager 8 personnes, soit l'équivalent de 2 à 8 voitures (suivant le nombre de passagers qu'elles contiennent) !

Figure 19 LaRochelle communication strategy: "Le Petit Quotidien" special edition children's newspaper

Source: CityMobil2, 2016, Final Conference

Figure 20 Children learning about the Oristano shuttle

Source: CityMobil2 Newsletter, 2015, Oristano Demonstration

Chapter 7 - Conclusion

The number of pilot programs that are implementing autonomous shuttles in public transportation is continuing to grow. For transit agencies that want to partake in such a pilot program, they need this comparative analysis report. This report examines previous pilot programs and answers the question of what principal elements and considerations transit agencies need to make informed decisions about implementing an autonomous shuttle pilot program. The elements and considerations highlighted in this report are intended to assist transit agencies in creating safe and viable systems through their pilot program testing. This report has identified three essential elements:1) site selection, 2) program design and 3) partnerships. The operational environment and right-of-way allocated for a pilot program are the main considerations of site selection. This report recommends that when transit agencies select a site for their pilot program, they allocate a right-of-way for the shuttle system that is appropriate to its operational environment. Safety should be the highest priority for an autonomous shuttle system and ensuring that the proper right-of-way is allocated for that system is essential. For example, a shared right-of-way should only be used in low populated areas with minimal pedestrian and cyclist traffic. Also, a generous amount of space is required to allow pedestrians and cyclists to pass without interfering with the shuttle's sensors. The program design element of a shuttle system includes the service, operation, and connections accessible to passengers. The first recommendation for a transit agencies' program design is that all shuttle systems offer ADA accessibility for its passengers to ensure inclusion for all to participate. This report also recommends that, at least initially, the system have an onboard operator. An onboard operator will educate passengers and help them adjust to the program. A third program design recommendation is that transit agencies offer connections and stops to places that generate a lot of foot traffic and are places that people want and need to visit. Beyond proving the shuttle's technical capability, transit agencies should also prove that the system could complement existing services and improve access. The final essential element, partnership, is an absolute necessity for transit agencies. Implementing an autonomous shuttle requires training, maintenance, engineering, day-to-day management, and data collection. Transit agencies need partnerships with research institutions, the public sector, and the private sector to help address all the requirements it takes to implement a pilot program. The partnerships made for an autonomous shuttle pilot program will influence the operation and outcome.

This report has identified four types of considerations that transit agencies need when implementing a pilot program. The considerations identified are: 1) cooperation, 2) evaluation, 3) phasing and 4) pilot program configuration. These four considerations have been identified because they supplement the three pilot program elements. It is not enough for transit agencies to establish partnerships with stakeholders, they also have to establish cooperation among them. This report recommends that during the planning phase transit agencies define the roles and responsibilities of all partners and stakeholders involved. By establishing these in advance, transit agencies can avoid confusion and delays during implementation and operation because all involved will understand who is responsible for what and when. Evaluation had been identified as a consideration for transit agencies because transit agencies are executing a pilot program and the purpose of a pilot program is to test and prove the viability of a shuttle system. Maintaining thorough evaluations will help transit agencies know what worked and what did not work. This will be especially helpful for when transit agencies are ready to incorporate an autonomous shuttle system into their transit services. Additionally, the data and information that the transit agencies collect will help other agencies who are looking to implement their own pilot program.

The third consideration this report has highlighted is phasing. Phasing is important for transit agencies because an autonomous shuttle needs to accumulate with its surrounding and be tested with different variables before it can begin transporting passengers. Transit agencies need to plan for a long testing phase to ensure safety for its passengers and other road users. The final consideration provided in this report is pilot program configuration. Transit agencies should consider different speeds for shuttle operations and additional infrastructure changes. Each possible operational environment and allocated right-of-way for a pilot program will require an adjustment to the shuttle's operational speed. This report recommends that when a shuttle operates on a dedicated right-of-way that the shuttle speed matches or is close to, the speed of the other vehicles. By keeping similar speeds, the system will cause less of a disturbance to other road users. For additional infrastructure changes, this report recommends that transit agencies increase road markings that indicate a shuttle has a right-of-way on a route and add an electronic message board to the shuttle. Additional road markings will make other road users aware of the system, and they can react appropriately to the presence of the shuttle. By adding a message board to the shuttle, it can further communicate to other road users that the shuttle is in operation and may stop at any moment. These additional infrastructure changes are recommended for transit agencies because they will help improve the safety of passengers and road users.

All framework elements, considerations, and best practices identified in this report are directly related to and driven by the project purpose. For example, projects that want to gain public awareness and acceptance of autonomous shuttles should have a robust communication strategy and operate in an environment where it will gain much attention like a city center or recreational district. Another example is a project that wants to validate the technology of autonomous shuttles; those projects should collaborate with private sector business who specialize in intelligent systems or research institutions focused on software development and operated in a more controlled environment. There are many variables to evaluate when undertaking an autonomous shuttle pilot program. This report has identified three essential elements, specific considerations, and recommended best practices for transit agencies. While this report does not cover all aspects of required efforts, it does provide transit agencies with an overview of what has been done, what worked, what did not work, and how different choices affect the project.

Future Research

Bits and Atoms (2017) ask whether transit agencies should operate their own autonomous vehicle services. This report helps transit agencies answer that question by providing them with a comparative analysis of executed autonomous shuttle pilot programs. Understanding the essential elements needed to implement a pilot program and how they relate to one another gives transit agencies the knowledge they need to confidently decide whether an autonomous shuttle pilot program should be tested as part of their transportation service. However, further research on the subject of autonomous shuttles in public transportation is needed. For autonomous shuttles to become a permanent alternative transportation solution, transit agencies need to evaluate whether or not an autonomous shuttle system is a practical application. While a pilot program will help transit agency learn if autonomous shuttles are feasible, further research and testing are needed to know if an autonomous shuttle system is an efficient addition to their transit services.

References

Arem, B. v., Happee, R., Knie, A., Madigan, R., Merat, N., Nordhoff, S., & Ruhrort, L. (2017). User Acceptance of Driverless Shuttles Running in an Open and Mixed Traffic Environment.

Automated Transportation in the (Driverless) Seat. (2015, July 10). Retrieved from European Commission: http://ec.europa.eu/research/infocentre/article_en.cfm?&artid=35237&calledby=infocentre&caller=SuccessStories&id=/research/star/index_en.cfm?p=ss-citymobil2&item=All

Bits and Atoms. (2017). *Taming the Autonomous Vehicle: A Primer for Cities.* Long Island City: Bloomberg Philanthropies.

Boersma, R. (2017). *Appelscha Case Study: an investigation into the implementation of automatic transport in the outlying area.* Rotterdam.

City of Austin Texas. (2018). *Right-Of-Way Management*. Retrieved from austintexas.gov: http://www.austintexas.gov/department/right-of-way-management

CityMobil2. (2016, June 1). San Sebastian ARTS Demonstration. San Sebastian, Spain.

CityMobil2. (2016, February 6). WP30 - Deployment. San Sebastian, Spain.

CityMobile2. (2016). *Experience and recommendations.*

Craen, S., Hoekstra, Loenis, & Schagen. (2017). *Advice Practical Test: Eemshaven Phase I.* Hague.

Dall'Oglio, A., Frisoni, R., Long, J., McMinimy, S., Nelson, C., Ranghetti, & Vollath, C. (2016). *Research for TRAN Committee: Self-Piloted Cars: The Future of Road Transport?* Brussels: European Union. doi:10.2861/66390

Dickens, M., & Neff, J. (2017). *2016 Public Transportation Fact Book.* Washington, DC: American Public Transportation Association.

Drieux, G. (2017, May). Sophia Antipolis Demonstration: Results and Lessons Learnt. CityMobil2. Retrieved April 2018, from http://www.citymobil2.eu/en/upload/Final_conference/3%20-%20Demonstration%20CASA%20-%20Guillaume%20Drieux.pdf

Easymile. (2018). *Our Products: Easymile*. Retrieved from Easymile: http://www.easymile.com/

Fagnant, D., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: opportunities, barries and policy recommendations. *Transportation Research Part A: Policy and Practice*, 167-181.

Graindorge, M. (2016, June 1). LaRochelle's ARTS Demonstration.

Graindorge, M., & McDonald, M. (n.d.). LaRochelle Demo Preliminary Results. CityMobil2.

Hars, A. (2016). Top misconceptions of autonomous cars and self-driving vehicles. *Inventivio Innovation Briefs*, 1-12.

Holguin, C., & Stam, D. (2016, March). Guidelines for implementation of CityMobil2: type systems. European Union.

Industrial Innovation and Diversification for Ligier Group. (n.d.). Retrieved April 4, 2018, from Ligier Group: http://www.ligiergroup.com/ligier-group/meet-the-ez10-the-driverless-shuttle.html

International Transport Forum. (2015). *Automated and Autonomous Driving Regulation Under Uncertainty*. OECD.

Joseph, H. (2018, February 9). Easymile Pilot Program Interview. (A. Hunter, Interviewer)

Lohmann, R., & Van der Zwaan, S. (2017). *When will autonomous transit be a reality?*

Mercier-Handisyde. (2016, February). Interview with Dimitris Papastergic. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2014, June). CityMobil2 City Selection. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2015, February). Lausanne Demonstration. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2015, Septemeber). Lausanne Demonstration Conclusions. *CityMobil2 Newsletter*. European Commission.

Mercier-HandiSyde, P. (2015, February). Oristano Demonstration. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2016, Fedruray). CASA Demonstratiopn. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2016, August). CityMobil2 Demonstrations: From Oristano to Donosita/San Sebastian. *CityMobil2 Newsletter*. European Commission.

Mercier-Handisyde, P. (2016, August). Demonstration in Donosita/San Sebastian. *CityMobil2 Newsletter*. European Commission.

Mercier-HandiSyde, P. (2016, August). Interview with Eneko Goia Laso. *CityMobil2 Newsletter*. European Commission.

Merriam-Webster Incorporated. (2018). *False Positive*. Retrieved from Merriam-Webster Dictionary: https://www.merriam-webster.com/dictionary/false%20positive

Merriam-Webster Incorporated. (2018). *Right-Of-Way*. Retrieved from Merriam-Webster Dictionary: https://www.merriam-webster.com/dictionary/right-of-way

Municipality of Ooststellingwerf. (2017, November 28). *Appelscha Automated Transport Pilot: Evaluation Report.* Retrieved from Ooststellingwerf Township: https://www.ooststellingwerf.nl/document.php?m=40&fileid=22747&f=107b4ddce444ea752c7c4e3cf98e606e&attachment=0

NHTSA. (2018, March 6). *Preliminary Statement of Policy Concerning Automated Vehicles.* Retrieved from National Highway Traffic Safety Administration: www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf

Papastergiou, D. (2016, February). Interview with Dimitris Papastergiou. (P. Mercier-Handisyde, Interviewer)

Pessaro, B. (2016). *Evaluation of Automated Vehicle Technology for Transit - 2016 Update.* Tampa: Center for Urban Transportation Research.

Polzin, S. (2016). *Implications to Public Transportation of Emerging Technologies.* Tampa: National Center for Transit Research.

Raptis, O. (2016, June). Trikala Demonstration Site: Large Scale Perspective. *CityMobil2 Final Conference*. San Sebastian, Spain.

Rodriguez, P. (2017). *Safety of Pedestrians and Cyclists when Interacting with Automated Vehicles; A Case Study of the WEpods.*

Schneider, A. (2015, September). CityMobil2 Newsletter. (P. Mercier-Handisyde, Interviewer)

Schoettle, B., & Sivak, M. (2014). *A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the U.S., the U.K., and Austrailia.* Ann Arbor.

Smith, B. (2014). A Legal Perspective on Three Misconceptions in Vehicle Automation. In *Road Vehicle Automation* (pp. 85-91). Switzerland: Springer International Publishing. doi:https://doi.org/10.1007/978-3-319-05990-7_8

Township Ooststellingwerf. (2017). *Pilot Self-Propelled Transport Appelscha.* Ooststellingwerf.

U.S. Department of Transportation. (2018, March 6). *Automated Vehicles for Safety*. Retrieved from National Highway Traffic Safety Administration: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Van der Wiel, J. W. (2017). *Automated Shuttles on Public Roads: Lessons Learned.* Spring Innovation Management B.V.

Van der Wiel, J. W. (2018, March). WEpods Pilot Program. (A. Hunter, Interviewer)

Zaccaro, H. (2017, July 10). *Rethinking First & Last Mile: Transit Driven Complete Streets Webinar Recap*. Retrieved from Smart Growth America: https://smartgrowthamerica.org/rethinking-first-last-mile-transit-driven-complete-streets-webinar-recap/

Appendix A - IRB Exemption Letter

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Gregory Newmark
Landscape Architecture/Regional and Community Planning
1093 Seaton Hall

Proposal Number: 9191

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 03/06/2018

RE: Proposal Entitled, "Approaching Autonomous Shuttle Pilot Programs in Public Transportation"

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §46.101, paragraph b, category: 2, subsection: ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278
comply@k-state.edu | k-state.edu/research/comply

Appendix B - Sample Interview Protocol

Email/Phone Call Recruitment Script

Hello, my name is Alicia Hunter. I am a graduate community and regional planning student at Kansas State University. I am researching applications of autonomous shuttles in public transportation. As part of my research, I am interviewing a variety people involved with organizing autonomous shuttle pilot programs. This study has identified you as a knowledgeable participate of the pilot program in ____city____, ____country___. I am emailing to ask if you would be willing to let me interview you. Our conversation should take about thirty to forty-five minutes.

If you would be interested in participating in this interview, please let me know when a good time would be to schedule. If you have any question, please do not hesitate to contact me, alicia7@ksu.edu.

Look forward to hearing back from you and thank you for your time-

Alicia Hunter
Masters in Regional & Community Planning
Kansas State University
alicia7@ksu.edu

Interview Protocol

Hello, my name is Alicia Hunter. I am a graduate community and regional planning student at Kansas State University. I am researching applications of autonomous shuttles in public transportation. As part of my research, I am interviewing a variety people involved with organizing autonomous shuttle pilot programs. I will analyze the interview responses to generate a framework of pilot program elements and recommend best practices. I have identified the pilot program in ____city____, ____country____ as one of my case studies.

Our conversation should take about thirty to forty-five minutes. Is this time still good for our call?

Thank you. I need to inform you that this study is considered research. Your participation is voluntary, you may skip any questions, and you can terminate your participation at any time. Do you consent to be interviewed?

Thank you for taking the time to talk with me today. Do you have any questions before we proceed?

Interviewee Background Questions

First, I have few questions about your role in the pilot program

1. What is your official title/role with the pilot program?
2. How long have you been working on this pilot program?
3. Who are the key stakeholders responsible for developing this pilot program?

Appendix C - CityMobil2 Stations at Shuttle Stops

Source: CityMobil2, 2016, Final Conference