

Feasibility of Electric Autonomous Shuttles in Easton

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Start Date: January 10, 2017

End Date: April 25, 2017

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I. Executive Summary

As the winner of the United States Department of Transportation's Smart City Challenge, Columbus, Ohio has been granted funding to deploy six low-speed, electric autonomous vehicles (EAVs) throughout the Easton Town Center/Morse Road area. These vehicles will act as a shuttle system to improve accessibility to public transportation while connecting people to both retail locations and jobs. EAVs are intended to solve traffic congestion issues in Easton by reducing the number of cars on the road. EAVs will also address the first-mile/last-mile issue, which involves a lack of transport to an individual's final destination from a given drop-off point. This report assesses the feasibility of this goal by determining if the target audiences will adopt the new technology. This report also researches five EAV companies to identify which would be most feasible for the Easton area.

To perform this feasibility analysis, a survey was crafted in coordination with the City of Columbus and United States Department of Transportation. The survey was conducted with the intent to better understand the Easton/Morse Road area, worker's and guest's habits, trust issues with the technology, and how the implementation of EAVs would benefit potential users. Results from this survey show that individuals using public transportation to get to the Easton/Morse Road area are less likely to use an EAV compared to those who use their own transportation. However, public transportation users were more willing to pay to ride an EAV, while those who drove themselves were less willing to pay to ride. Age data from the survey shows young individuals are more likely to adopt the technology when compared with older generations. Other demographic data had less significance in the adoption rates of EAVs. Many potential EAV users felt they would better trust EAV technology if there were a trained professional monitoring the system, or other safety features on board.

Of the five EAVs researched for this project, a small American-based EAV manufacturer, called Local Motors, was determined to be the best fit for the city. Local Motors' EAV can meet the needs of its users, while benefiting the city. Bringing Local Motors' product to Columbus will provide a long-lasting EAV, and bring about future opportunities for the company to open a manufacturing facility within the city.

Based on these findings, it is recommended that the city provide a demonstration of the EAV technology for potential users, monitor the EAVs with trained professionals, provide free services when first implemented, and choose Local Motors' EAVs for operation in Easton. The addition of EAVs to Columbus will have the capacity to improve the city's transportation network, allow for greater social well-being, and provide a transportation means in a given area for those who have none.

II. Introduction

Recently, the City of Columbus won a \$40 million-dollar grant from the United State Department of Transportation (USDOT) for out competing 77 other cities nationwide. The grant was awarded to a city with a vision for technology that can improve the lives of its residents, including "Connect Columbus residents to safe, reliable transportation that can be accessed by all" (AV Working Group Meeting). In addition to the \$40 million, Columbus has received additional funding from public and private parties, boosting this number up to over \$400 million. Part of this fund is dedicated to bringing six Electric Autonomous Vehicles into the Easton Town Center and Morse Road area to act as a shuttle service to get people to and from their destination, also known as the first-mile/last-mile transportation issue. This issue involves a lack of transportation, which often forces people to work to their work place, or be less willing to find a job in areas farther away from a public transit drop off point. This report has been designed to

help the City of Columbus determine the likelihood of Easton Town Center/Morse Road guests, including shoppers and workers, to adopt and utilize EAVs. To conduct the needed research, a survey was created with specific questions geared towards understanding Easton patron's patterns, demographics and adoption/trust towards EAVs. A second objective of this report is to make a recommendation to the City of Columbus in regards to which EAV model to implement in Easton. This recommendation will be made based on research of EAV manufacturers and how their products address the needs of the city.

From the survey the team conducted, 75 responses were collected from both workers and shoppers with various demographic backgrounds. The results collected through the survey shed light on many questions and concerns that Smart Columbus has about the implementation of the EAV shuttles in Easton. The main findings identified trends in user adoption, demographics, Easton patron habits, willingness to pay and trust in EAVs. Overall, this indicated that EAV shuttles in Easton could be utilized, however, did not yet have a strong amount of consumer trust. The explicit breakdown of the findings are discussed in detail throughout the report. The survey results allowed the team to make recommendations for the implementation processes that may benefit Columbus.

III. Research Methods

Throughout the research project, varieties of different methods were used to ensure the survey was generating the most unbiased, representative data possible. When conducting a survey, it is critical to design it in an objective way while also generating responses from a wide range and wealth of varied and diverse responses. To do this, a basic survey was created that sought to identify the basic transportation needs and patterns of the people of the Easton/Morse Road area. The initial survey was small and designed to allow freedom of response from Easton

guests. The survey draft was sent to the City of Columbus, where detailed feedback was received, suggesting more quantifiable answers. This allowed respondents to choose from different options expressing different levels of agreement to a given question, the survey was then sent to the USDOT for further review. Feedback from the USDOT helped clarify potentially confusing questions. This review process helped create a survey designed to efficiently identify transportation needs and patterns as well as basic demographic information from respondents.



Figure 1: Survey Hotspots¹

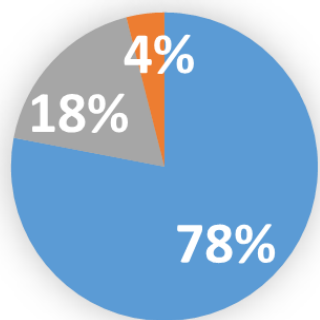
After finalizing the survey, it was then distributed in the Easton/Morse Road area. To generate the most representative sample possible, two goals for surveying patterns were set. First, the survey was to be conducted at different times, this accounted for transportation needs at different times of the day. Second, the survey was conducted in a variety of various regions in the Easton/Morse Road area to identify transportation patterns amongst respondents. This survey took place primarily throughout the Easton Town Center and Central Ohio Transit Authority (COTA) Transit Center to effectively manage time constraints and seek to maximize the number of respondents (Figure 1). Finalizing the survey took longer than originally anticipated, leaving a much shorter timeframe to work in the field and collect results. Results

were collected with diligence, allowing for a total of 75 participants to be reached. In congruence with the conduction of a survey, several EAV shuttle producers were identified by the City of Columbus and researched to determine which would be most feasible for deployment in the Easton/Morse Road area. Research and discussion with EAV manufactures took place to conclude which EAV would be best suited for the Easton/Morse Road area. The deciding factor was established based on which EAV company could be most beneficial to Columbus and best manufacture an EAV that could the needs of the users.

IV. User Adoption

When examining the feasibility of deploying EAV shuttles in the Easton/Morse Road area, the most fundamental question is whether people will use the shuttle. In the survey, there were several questions aimed at determining if and to what extent people would be willing to use autonomous driving technology on a regular basis. When asking whether or not people would use autonomous driving technology, the survey was divided between individuals in the Easton area for shopping, dining, and entertainment or individuals who are working; this information

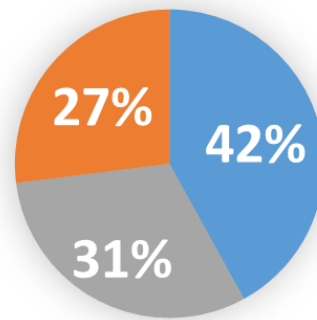
**Anticipated EAV Adoption
(Other Transportation)**



■ Yes ■ No ■ Maybe

Figure 3: Private Transportation Anticipated User Adoption

**Anticipated EAV Adoption
(COTA Users)**



■ Yes ■ No ■ Maybe

Figure 2: COTA User Anticipated User Adoption

could indicate different transportation patterns between the groups. Respondents traveling to the

Easton area in a personal vehicle or other form of private transportation (carpool, bicycle, etc.) overwhelmingly support the idea of using an autonomous shuttle to travel from destination to destination once in the Easton area. The survey indicated that 78% of town center guests said they would use the shuttle, 18% would not, and 4% said they might use the shuttle (Figure 2). Current COTA users are less willing to ride an autonomous shuttle, with 42% saying they would use the shuttles, 31% said they would not, and 27% might use the shuttles (Figure 3). One may assume those using existing public transportation system would be more willing to adopt EAV technology seeking to improve the existing public transit system. However, guests of the Easton area show more trust towards EAV use.

There are several possible explanations to describe the low rates of willingness to ride amongst public transportation users. Firstly, when surveying COTA users, there was a clear sense of dissatisfaction towards the existing public transportation system. Several respondents did not seem to value increasing the number of shuttles on the road when the current issue is not the number of COTA buses on the road. Conversely, they expressed concerns over buses and COTA's lack of efficiency. Furthermore, respondents did not wish to pay for additional transportation. Many respondents expressed they would be willing to pay about the same as a COTA bus if the cost of the new shuttle would be included in their existing weekly or monthly COTA pass. Finally, it is important to recognize demographic differences between those using COTA to travel to the area and those using private transportation. The annual household income of a COTA user is far less than that of someone driving himself or herself or using another form of private transportation (Figure 4). According to the New York Times, the average college graduate in America earns approximately 74% more money annually than a worker with only a high school diploma⁶. If this is true, the lack of potential adoption from COTA users could arise

from this stark income gap and, perhaps, lack of education. Many COTA users interviewed had a strong distrust of driverless technology, which could be attributed to their lack of familiarity with such technology in comparison to those using private transportation. In order to maximize adoption and serve the immediate needs of COTA users in the area, more outreach and education regarding autonomous vehicles is needed amongst this demographic.

Mode of Transportation	Income
COTA Users	\$34,285.00
Private Transportation	\$85,768.33

Figure 4: Income Levels between COTA Users and Non-COTA Users

V. Demographics

The survey has four questions relating to demographic information, including race, age, gender, and income level. These four questions are used to determine how EAV adoption rates vary in relation to each demographic response, and how they help discover any trends existing within the characteristics of adopters. The survey conduction process aimed to get responses from a diverse pool of individuals that would represent the Easton/Morse Road population. Of the survey respondents, 85% identified

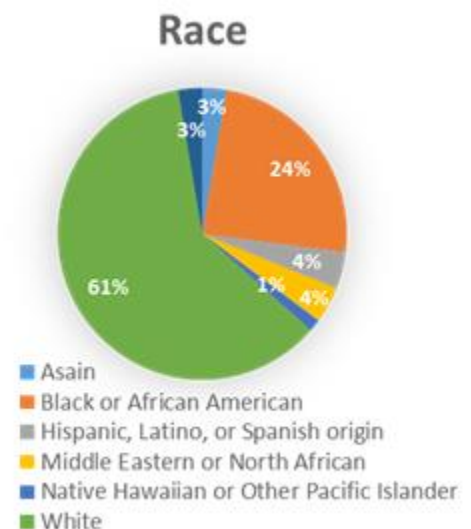


Figure 5: Race Distribution of Survey Respondents

as either White or Black/African American, with the remaining 15% coming from other descents (Figure 5).

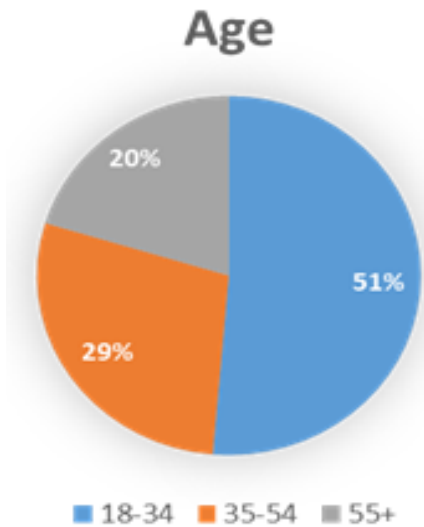


Figure 6: Age of Surveyors

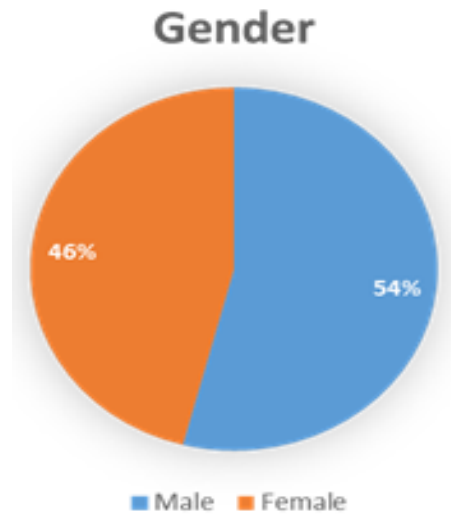


Figure 7: Gender of Survey Pool

Age distribution results shows just over half of those surveyed were between 18-35 years old, and just under half were older than 35 (Figure 6). The younger age group was most interested in Easton for entertainment, with 27 respondents saying they were in Easton/Morse Road area for entertainment purposes and 11 respondents saying they were in the same area for work. The older age group had 20 individuals go to Easton/Morse Road for entertainment and 13 visiting Easton/Morse Road for work. Results showing the gender distribution were almost split equally, with 46% of the sample being female, and 54% being male (Figure 7). Visual observations in the Easton/Morse Road area confirmed this, with the sample population being nearly homogenous at baseline. It should be noted that, when approaching a family to conduct a survey, the adult male would often take the initiative to respond, which could confound results.

Understanding the demographic data as it relates to EAV trust levels yielded some interesting results. First, there are no direct patterns identified in relation to income level as

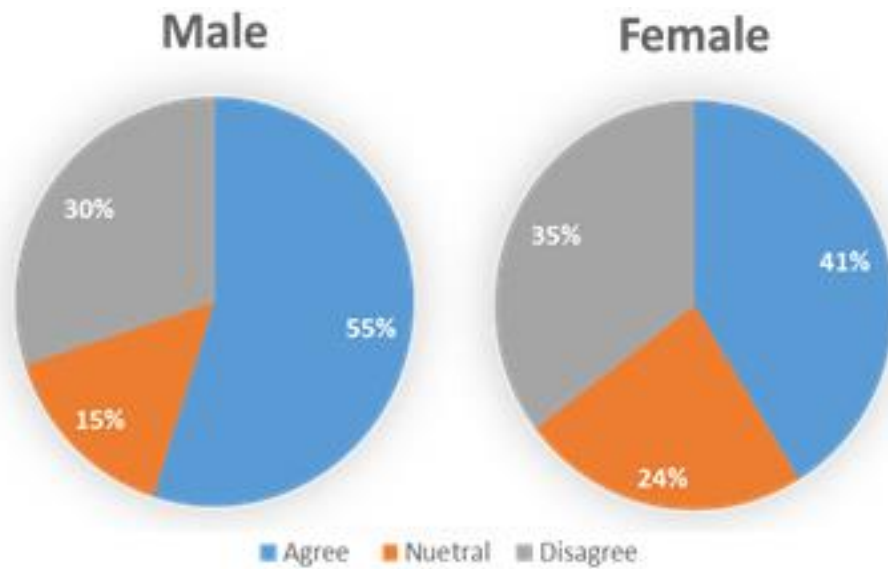


Figure 8: Gender Trust Comparison

related to EAV trust. It was theorized that those who took public transportation to the Easton/Morse Road area, often those with lower income, would have been more likely to use an EAV shuttle service as transport around the area, but there was not a direct correlation in this area. Second, the survey revealed that gender and age showed a divide in EAV adoption. Gender patterns, as related to EAV trust, are shown in Figure 8, where the question was asked

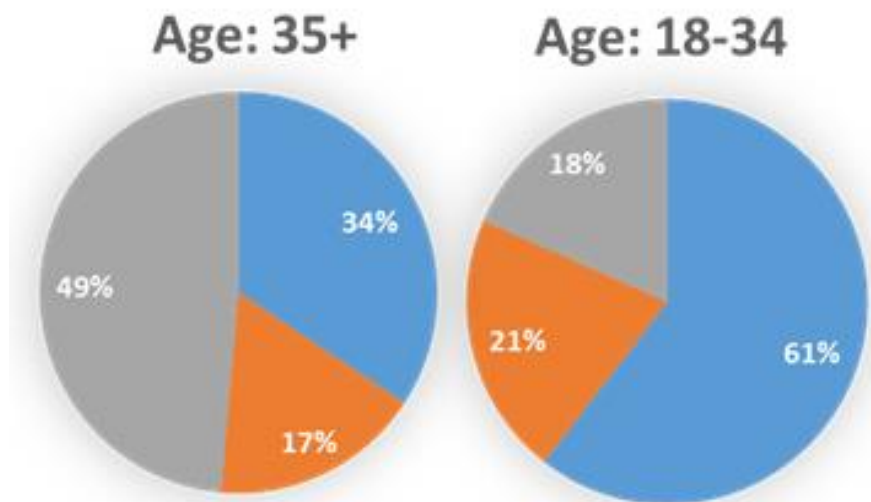


Figure 9: Age Comparison

“[Do you] trust EAVs?” The results revealed that 55% of men trusted the technology, while 41% of women shared this trust (Figure 8). Third, regarding EAV trust, a small correlation was

found relating to race, with 49% of respondents who identified as “White” said they trusted EAVs, but only 33% of respondents who identified as “Black or African American” shared this trust. Other race categories did not have enough results to make any correlation. Finally, age revealed a divide between the younger and older generation, as they relate to EAV trust (Figure 9). While the older age group was less trusting of the new technology, the younger age group reported a higher willingness to trust EAVs. These results are similar to what was found in a study performed by AAA, which found that 70% of surveyed millennials want self-driving technology⁸.

VI. Easton/Morse Road User Habits

After observing and surveying the habits of people in the Easton and Morse Road area, several trends should be noted. Survey respondents spend time in Easton/Morse Road area either for work or entertainment purposes, and would travel an average of 14.8 miles to get to the area

Distance from residence to Easton/Morse Rd Area (Miles)

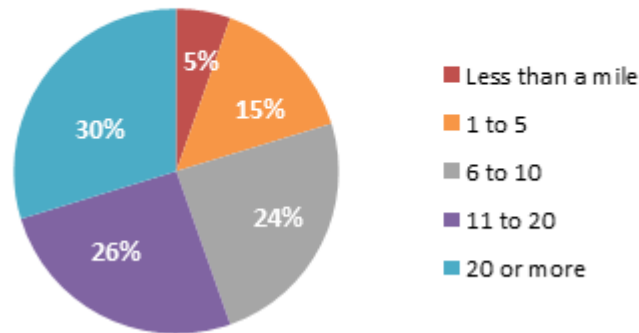


Figure 10: Miles Traveled to Easton from Home

from their place of residence (Figure 10). The behavior of workers and shoppers varies. Concerning workers, 22% are driving alone to get to work while 74% are using some form of public transportation. For those specifically using COTA to get to work, about 73% of them are

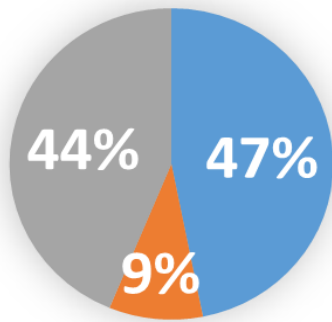
walking to get to their bus stop and from there 69% of them travel up to two miles to get from that stop to work. When people were asked about using a small, driver-less shuttle to bring them closer to work from the last COTA stop, the results are somewhat scattered: 42% said they would be willing to try, 30% said no, and 27% said maybe. Based off the reactions of the people when asked this question, there is a somewhat even split between wanting to use it to cut down travel time and trusting such a new technology.

For the Easton Town Center guests, most people initially drive themselves to get to the area with only a few using other modes of transportation such as carpool (6%), public transportation (6%), or Uber, Lyft or taxi (2%) to get around. When people are shopping in the Easton area 90% say they are visiting multiple destinations and 86% of them walk to get from site to site. While in the area, people tend to travel in groups of two, three and five most frequently. This information can be extremely valuable; for example for looking at larger group sizes, one can insinuate that people may be more inclined to use the EAV since they could all travel together to get from location to another instead having to all drive separately. Of the EAVs Columbus is looking to adopt, their capacities range anywhere from eight to fifteen people, so this could allow for larger parties to travel together. At the same time, this can only be true if there are not many people using the shuttle already. Easton does have a shuttle in place, a custom trolley that carries guests around the Town Center for free. However, about 83% of people have not used the trolley while only 16% mention that they have. Almost all the people that have used the trolley were those surveyed in the actual Town Center as opposed to COTA's Transit Center.

VII. Willingness to Pay

Willingness to pay is an important measure that can identify how well the community would adapt EAV use in the Easton area. When looking at all 75 respondents from the survey, the team

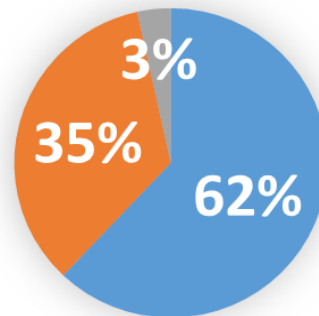
Willing to Pay for EAV Ride?



■ Agree ■ Neutral ■ Disagree

Figure 11: WTP of Surveyors

Willingness to Pay to Ride EAV Compared to COTA



■ About the Same ■ Less ■ More

Figure 12: WTP of Guests Compared to COTA Users

found people's responses are about even when asked if they are willing to pay (47%) or not willing to pay for an EAV ride (44%) (Figure 11). Most individuals who drove themselves to Easton were unwilling to pay to ride in an EAV. Some explanations of the surveyor's unwillingness to pay included that they would rather walk or drive to other destinations, or they did not trust EAV shuttles yet. Those who took public transit into the Easton/Morse Road area, were more willing to pay for an EAV. 62% of the respondents who were willing to pay for an EAV, were willing to pay about the same as the local \$2 COTA fee (Figure 12). This high percentage indicates worker's interest in a first-mile/last-mile solution being implemented in the Easton area.

VIII. Trust in EAVs

The survey conducted in Easton entailed three questions involving human trust in EAVs. It was suspected that the trust level towards EAVs would be low due to the technology being simply new. In fact, while conducting the survey some people needed a deep explanation of what an EAV was and admittedly had not yet heard of driver-less vehicles.

The first question regarding trust in EAVs was “I trust driver-less vehicles.” Out of 75 responses; 16.2% strongly agreed they trusted EAVs, 32.4% agreed they trusted EAVs, 18.9% neither agreed or disagreed, 17.6% said they disagreed and 14.9% said they strongly disagreed in trusting EAVs (Figure 13). Overall, less than 48% of people agreed that they would trust a driver-less car. This is something to reflect upon when considering the implementation of

More comfort if the driver-less vehicle had a steering wheel?

More comfortable with trained professional monitoring the vehicle?

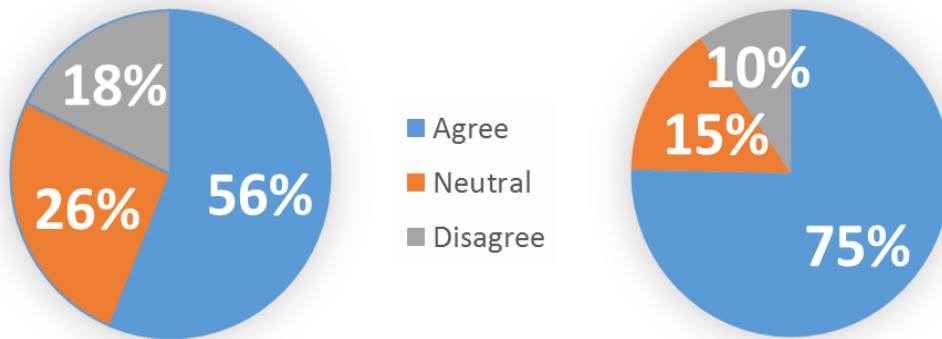


Figure 13: Additional User Trust Options

EAVs in Easton and it also raises more questions. For example, if majority of people do not trust EAVs will it be beneficial to have them in Easton? Or possibly, once the technology advances and becomes mainstream, will closer to 100% of the population trusts them?

The second survey question concerning the trust of EAVs was “I would feel more comfortable if the driver-less vehicle had a steering wheel.” Out of 75 respondents: 32.9% of people said they strongly agreed that a steering wheel would make them more comfortable,

23.3% agreed, 26% neither agreed or disagreed, 4.1% disagreed and 13.7% strongly disagreed that a steering wheel would make them feel more comfortable (Figure 13). Over 50% of respondents admittedly stated that a steering wheel would make them feel more comfortable riding in a driver-less vehicle. However, when it came to the less than 20% that admittedly disagreed that a steering wheel would create comfort in the EAV the reasoning was split. Some respondents noted that the shuttle would be driver-less, so there would be no need for a steering wheel and they were okay with that. On the flip side, some respondents commented that they simply did not trust, nor would ride in an EAV so it did not make a difference to them if the vehicle had a steering wheel or not. However, the general consensus was that a steering wheel in the vehicles would ease the minds of a majority of potential riders.

The third and final question on the survey concerning trust in EAVs was “I would feel more comfortable if there were a trained professional monitoring the vehicle.” This data displays that out of 75 respondents, 75% would feel much more comfortable and therefore more willing to ride in an EAV if there were a trained professional monitoring the shuttle. Most individuals who disagreed with this question were young individuals with a fairly high-income level and were very enthusiastic about the idea of EAVs in Easton/Morse Road Based on this data. It is also clear that the EAV shuttles in Easton would be more successful if they had steering wheels and/or professionally trained monitors who would supervise the vehicles. However, because it is speculated that the lack of trust in EAVs is due to the technology being so new, this suggestion is only for the implementation process of the vehicles. Once they are successfully implemented and the riders build trust, there will be no need for steering wheels or someone monitoring. According to Everett Rogers's theory of the diffusion of innovation, the adoption of new technologies takes time. At first, a small proportion of the population begins to use, or adopt, a

new technology. As more and more people grow comfortable with the new technology, however, the rate of adoption increases. This adoption theory may prove to be true for EAVs as well as trust increases over time³.

IX. EAV Selection Process

After first meeting with the City of Columbus, there were three EAV shuttles identified by the City: Local Motors, Navya, and Easy Mile.

	Local Motors	EasyMile	Navya	Induct	Innova EV
Top Speed	25 mph	24.9 mph	28 mph	12.5 mph	35 mph
Operation per charge	32 miles	14 hours	5-13 hours	24 hours	150 miles
Technology	IBM Watson	N/A	N/A	N/A	N/A
Special Features	IDM Watson and 3D printed.	Conventional Steering wheel and brakes	Wireless charging	Topless	4G LTE/WIFI
Charge Time	4.5 hours	8 hours	4-8 hours	N/A	1 hour
Aprox. Cost	\$250,000	\$250,000	\$250,000	\$250,000	\$13,000
Capacity	12	12	15	8	2
Battery Type	Lithium-ion (LiFeP04)	Lithium-ion (LiFeP04)	Lithium (LiFePO4)	Lithium Ion	Lithium Ion
Payload	2,200 lbs	3,748 lbs	2,646 lbs	N/A	N/A
Country	United States	France	France	France	United States

Table 1: EAV Company Comparison (Appendix B)

In addition to these three, Induct and Innova EV were also identified as producers worth considering. To determine which EAV would be best suited for the Easton/Morse Road area, research completed for each company, examining both the specifications and features of each shuttle (Table 1). Furthermore, a phone interview with the Vice President of product development at Local Motors provided a more in-depth look into the development behind EAV designs. These various methods helped determine which EAV would be best suited for Easton's needs as well as which company may provide the best benefit to the city of Columbus. Below is a chart displaying the features of the five researched EAVs.

All of the EAVs are similar in design, except for the Innova EV, which is a small two seater vehicle. A vehicle carrying two individuals, can provide small group transportation services, but will be unable to provide shuttle services to large groups. The Induct EAV is not enclosed, unlike the others, which will be problematic during Ohio's colder weather seasons, and maybe better suited for entertainment purposes in the summer. The Navya, EasyMile, and Local Motors EAV all have similar costs and can each hold the same number of individuals, with the exception of Navya, which can hold 15. The charge time of Local Motors and Navya is similar at around 4 hours, with EasyMile having a charge time of 8 hours. Most EAVs have their operation time reported in hours, except Local Motors, which is reported in miles. Additionally, each vehicle has its own special features, such as wireless charging, ability to add conventional vehicle equipment, and more. From the interview with Hugh Palmer, the vice president of product design at Local Motors, it was discovered that their product would have double the battery life and the ability to wireless charge for its 2018 release. Hugh Palmer also discussed the company's business operations, including the ability to open a micro factory in areas where

their EAV is used. The potential of opening a micro-factory in the Columbus area to produce these vehicles was also discussed in the interview, and was suggested as a real possibility.

Based on the fact sheet above (Table 1), as well as the interview with Hugh Palmer, Local Motors has been selected in this report as the most beneficial EAV for the area. This selection is based on Local Motors having the shortest charging time of all the listed EAVs, allowing it to spend less time at charging stations. The Local Motors EAV can also be completely autonomous with wireless charging, which does not require a human to assist in the plugging in and unplugging process. Finally, Local Motors' EAV can meet any requirements for the creation of the shuttle in America, while potentially bringing about potential economic opportunity to Columbus.

X. Recommendations for Columbus

Over the course of researching the feasibility of EAVs in Easton, five recommendations were made for the City of Columbus. It is important to note there were two limitations of this current analysis. The first is that there were time constraints to conduct the survey, which was due to a longer than expected survey review process. This also limited the number of people surveyed, which could have been more if time permitted. The second was the limited number of workers using COTA who were available to survey compared to a larger amount of Easton guests available.

1. Provide EAV Demonstration

Survey results show that potential EAV users are still skeptical of the technology and idea of a driverless shuttle. It is recommended there be test rides in an EAV for the first few months before full commitment. There should also be multiple days dedicated to having an EAV demonstration in Easton to help users feel more safe and confident in the shuttles. A successful

demonstration of the technology may allow for a greater amount of trust to be placed in the EAV, possibly increasing usage rates.

2. Use Trained Professionals

75% of surveyors reported they would feel safer if a trained professional was inside; therefore, it is recommended that trained professionals be inside the vehicles when the EAVs are first implemented. They should remain in the vehicles until a higher level of trust is established between the users and the vehicle or until specific driver-less vehicle legislation is passed in the state of Ohio.

3. Specialized EAV Routes

If more shoppers are going to use the EAV, a higher emphasis should be placed on EAV routes designed specifically for that user group.

4. Free Shuttle

EAVs should remain a free service at first, and charge a small fee or be accessible by COTA passes in the future. This is due to a lack of willingness to pay of potential shuttle users, who may have a higher willingness to pay after the shuttle is implemented and more user trust exists with the EAV technology.

5. EAV Recommendation

After researching EasyMile, Induct, Innova EV, Local Motors, and Navya; based on the analysis, it is recommended that Local Motors' EAV is selected for Easton. Local Motors is an American company that makes EAVs called Olli, they are 3D printed, and equipped with IBM's Watson technology. In 2018, Local Motors EAVs will have wireless charging for their shuttles and extended battery life for their vehicles⁴. The company can put in a micro-factory in Columbus where they can 3D print vehicles, which could bring financial and economic opportunity to the area.

V. Conclusion

For workers to get to work from a bus stop they often walk, sometimes up to three or four miles. Known as the first-mile/last-mile issue, public transit users have to allot extra time for their commute to work or journey back home because their nearest bus stop is a considerable walk. Additionally, shoppers who visit multiple destinations in Easton often drive themselves if their destination is not within a short walk. The majority of shoppers would be interested in using a driverless shuttle while many workers that use public transit are less likely to use such as service. The majority of shoppers said they would not be willing to pay for the EAV, but most of the surveyed workers indicated a greater willingness to pay for this service. An overwhelming number of people said they would feel safer in a driverless shuttle if it were monitored by a trained professional. Respondents also felt safer if the shuttle would be equipped with conventional vehicle equipment, such as a steering wheel and brakes. Age also factored into the adoption of EAVs, with younger generations being more willing than older generations to adopt the technology.

To reiterate the recommendations, research found Local Motors to be best suited to provide EAVs in the Easton/Morse Road area. Their product successfully meets the needs of Easton users and provides the possibility for Columbus to become an automotive manufacturing city. Additionally, Columbus should demonstrate the EAV technology to spread awareness about the shuttle, while also working to gain the trust regular EAV users. A trained professional should remain in the vehicle until enough trust is established with EAV technology to remove them. While usage should remain free at first, the shift to a small payment or access through COTA passes should be considered for the future. With the addition of an EAV to Easton, opportunity exists to expand the city's transportation network and help connect workers and guests to their destinations while gaining user trust, solving first-mile/last-mile issue.

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Appendix

1: Dataset #1: EAV Feasibility Survey Data - Excel

- Source: Survey conducted by the members of this group - results found below:
- <https://docs.google.com/forms/d/e/1FAIpQLSccebPGnAsMbJUTA1w3h4M2tpVlkS-DqFCAmnp2N9ezrI89xQ/viewanalytics>
- Description: This survey was created in coordination with the City of Columbus and Department and Transportation. All results were collected in the Easton/Morse Road area between March 20 and 28th.

2: Dataset #2: EAV Fact Sheet – Excel

Sources:

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- Lambert, F. (2015). *Switzerland will have all-electric and fully autonomous buses as soon as next year [Gallery – Video]*. *Electrek*. Retrieved 10 April 2017.
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- Description: Numerous sources were used to compose a fact sheet comparing the 5 researched EAVs side-by-side. This comparison allows for the features and benefits of each EAV to be seen across the board.

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