Autonomous Vehicles and Transportation Equity in Pittsburgh

The Major in Ethics, History, and Public Policy
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Ian Asenjo
Cameron Dively
Margaret Edwards
Zachary Ettensohn
Jeremy Goldstein
Gaurav Gupte
Alison Hoffman
David Matvey

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Executive Summary

Autonomous vehicle (AV) technology is rapidly improving today and will become increasingly prevalent in the near future. At the same time, public transportation in the Pittsburgh area is struggling to provide adequate service to all residents who need it. With the emergence of AV technology, Pittsburgh is presented with an opportunity to address transportation woes in the city and surrounding suburbs. However, local officials must be careful to ensure that AVs improve rather than exacerbate the current inequity in access to transportation.

Pittsburgh's recent gentrification trend is partially a result of the local technology industry boom. As more technology companies come to Pittsburgh, more low-income residents will be priced out of their neighborhoods and forced to seek housing in cheaper suburbs. Even though low-income residents have the greatest need for public transit, end of the line suburbs are underserved by the current public transportation system. Pittsburgh should take into account that growth in the local AV industry could potentially worsen gentrification and force out lower-income residents to cheaper suburbs. This trend will further complicate problems with the local transportation system.

In order to gain an understanding of the local transportation system, we collected information on the Port Authority of Allegheny County from a variety of sources including the Port Authority itself, PennDOT, and local media reports. Our research identified three main groups that would particularly stand to benefit from better public transportation service. The first two groups are the elderly and people with disabilities, both of whom currently benefit from the ACCESS program. The ACCESS program has had trouble hiring sufficient drivers, which in turn has resulted in inadequate access to the program for eligible recipients. AVs present unique

opportunities to supplement services for those like the elderly and disabled who cannot drive themselves.

The third main group in the Pittsburgh area that could use improved access to public transportation are denizens of inner ring suburbs of lower wealth and income. Many residents who live in these suburbs do not have access to automobiles and therefore require public transportation. However, since these communities are at the end of bus lines, they are subject to less frequent bus service and are particularly vulnerable to budget cuts. The transportation problem of low-income suburban communities is our report's primary focus.

This report includes a case study of one such suburban community, Duquesne. The case study illustrates the difficulty that local residents have in accessing transportation and how that negatively impacts their quality of life. During the course of our research, we met with community leaders and residents in Duquesne to discuss their transportation concerns. Lack of transportation plays into the cyclical poverty of Duquesne. Without transportation, residents cannot easily access job opportunities or maintain their health.

Pittsburgh should work toward equity of access to transportation because it is vital to ensuring equal opportunity in life for local residents. It is to that end that we call for utilizing the new technology of autonomous shuttles to address concerns such as the First/Last Mile problem (FLM) where distances from homes to bus stops are too long to walk. In Duquesne, a particularly egregious instance of FLM exists for some 600 residents of the Hilltop Parkview Manor Apartments who have to walk a long, dangerous path to get to the nearest bus stop.[1]

[1] Nickole Nesby, interview by Ian Asenjo and Zac Ettensohn, 03 November 2017.

In order for Pittsburgh to gain access to the latest AV technology like shuttles, the city will have to attract AV companies to conduct research and development in the area. Pittsburgh should mitigate the effects that gentrification in the city has on low-income suburban communities by promoting policies that allow lower income suburbs to share in the benefit of new technologies developed in the city, particularly those that will increase residents' access to affordable transportation.

Our recommendations were informed by the often inequitable ways that past transportation innovations were implemented in Pittsburgh. In the late 19th and early 20th century the streetcar had the capability to transport people faster over longer distances than horse-drawn predecessors, but the fares often made streetcars less accessible to lower income residents.[2] After World War II, Pittsburgh adjusted to make the city more appealing to middle class consumers and more accessible to their automobiles. This included the haphazard construction of new highways, loop roads, and parking lots in places like the Hill District and East Liberty. For decades thereafter, communities had to deal with the harm that the disruptive construction projects caused, including a hindrance to mobility as connecting streets were eliminated and bus routes were cut.[3]

Since transportation innovations can have positive and negative outcomes, Pittsburgh should not lose sight of the needs of its most vulnerable residents. AV technology should be implemented to benefit underserved communities like Duquesne first. If lower income communities are not prioritized to benefit from AVs, inequity of access to transportation could

[2] Joel A. Tarr, "Transportation Innovation and Changing Spatial Patterns in Pittsburgh, 1850-1934," *Essay in Public Works HIstory* (April 1978): 21-22.
[3] Mindy Thompson Fullilove and Rodrick Wallace, "Serial Forced Displacement in American Cities, 1916–2010," *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 88, No. 3 (2011).

be further exacerbated because wealthier residents who rely more on private AVs will rely less on public transportation. In such a case, revenue for public transportation would subsequently fall, leading to more cuts for end of the line suburbs who have not been given priority for implementing AV solutions to transportation.

We recommend that the City of Pittsburgh work with nearby suburbs to implement autonomous shuttles into their communities. There are many companies implementing their autonomous shuttles in cities around the world. These companies are competing with each other for good publicity and the ability to test their technology. Pittsburgh, with its advantageous institutional wealth of AV experts, can likely attract an autonomous shuttle company to implement its technology to solve FLM problems in suburbs like Duquesne.

We also recommend that autonomous shuttles be implemented in areas where there are high levels of ridership across short distances. This could be somewhere like the Fifth and Forbes Avenue corridors near the University of Pittsburgh and Carnegie Mellon University. In areas like these, large amounts of short-range riders utilize buses that also serve long-range riders, creating inefficiency for long-range service. The needs of short-range riders could be addressed by running autonomous shuttles on a loop in the area, freeing up buses that otherwise would be spent inefficiently.

Autonomous shuttles could also be set to run on a constant loop in underserved communities, giving residents transportation to local businesses and other destinations that are not necessarily within walking distance. While autonomous shuttles are being implemented, we recommend that the City of Pittsburgh and surrounding suburbs look into the HART HyperLINK system that was established in Tampa to solve FLM problems there. The system uses a

smartphone app to call a car to pick up a resident and drop him or her off at the nearest bus stop based on the time of the bus' arrival. This system could be used as a stopgap while autonomous shuttles are being implemented and could potentially improve the implementation of autonomous shuttles by collecting data on FLM service.

Another recommendation of our report is to designate some buses for testing autonomous technology. In 2016, Washington state's public transit agency Pierce Transit adapted seven buses to use Mobileye AV technology. When the buses equipped with the AV technology were found to be far less accident prone, the Federal Transit Authority awarded Pierce Transit a grant to implement the technology on all of its buses.[4] While the technology is currently expensive, we recommend that the Port Authority partner with local AV technology companies to implement similar technology to reduce accidents and lessen fuel consumption.

The practical utilization of synchronized transportation modes like autonomous shuttles, HART HyperLINK rideshare cars, and buses depends upon a consistent price model and payment method. As such we recommend that the City of Pittsburgh start implementing "smart card" systems like the one Nashville recently began to explore.[5] City residents who receive public subsidies for transportation can be negatively impacted by having to pay out of pocket costs for one leg of their otherwise subsidized trip. A smart card system could synchronize the costs from different agencies for various legs of a trip. It could also provide a simple payment method and a stable price model that accounts for subsidized riders.

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[4] "Pierce Transit receives $1.66 million grant to install bus safety technology," *Suburban Times*, 22 January 2017, accessed 10 December 2017, https://thesubtimes.com/2017/01/22/pierce-transit-receives-1-66-million-grant-to-install-bus-safety-technology/.

[5] Joey Garrison, "Nashville explores linking Uber, Lyft to Metro bus system," *Tennessean*, 28 March 2016 .http://www.tennessean.com/story/news/2016/03/28/metro-explores-linking-uber-lyft-bus-system/82336598/.

The successful and safe implementation of AV technology will require updates to current infrastructure. We recommend that Pittsburgh and surrounding suburbs work to paint clear, bright lane markings so that AV cameras and LIDAR systems can function to the best of their ability. Another important infrastructure update is to install vehicle-to-infrastructure (V2I) technology in traffic lights and road signs. The V2I technology interacts with sensors in vehicles to improve adherence to traffic signals and could be used to improve traffic flow as a whole.

Pittsburgh's ability to access innovative AV technologies for improving local transportation will depend on its ability to attract AV companies to the region. To help Pittsburgh distinguish itself as a center of AV innovation, we recommend designating a nearby stretch of road for AV research like the Smart Mobility Corridor near Columbus, Ohio. Policymakers should consider Highway 43 in the South Hills. The 2017 Pennsylvania state budget set aside $11 million for smart corridor development and the federal government implemented a price-matching scheme for up to 40% of costs in Ohio. Given theses funds, the Pittsburgh area could implement a smart corridor with relatively little financial risk. The smart corridor in Ohio has helped raise $217 million in investments in the Columbus area from different companies and grants, suggesting that similar investments could be made to benefit Pittsburgh were there to be a smart corridor. With little competition for the millions of dollars in state smart corridor earmarks, Pittsburgh should hurry to forward a proposal for designating and building a smart corridor.

The Pittsburgh area stands to change greatly as a result of the imminent transportation revolution of AVs. The technology has the potential to be used to further equity and to address the inadequacies of the public transportation system. Ensuring that AVs are implemented in an equitable way will require devotion of policy makers to address the needs of vulnerable

communities and their residents first so that the AV era does not exacerbate existing inequity. AVs can be used to address problems associated with gentrification that is caused by a growing technology sector. We must learn from past mistakes that were made in prior transportation revolutions that disrupted and harmed low income communities' mobility so that wealthier residents could benefit from the convenience of improved technology. Pittsburgh should use AVs to further the cause of access to transportation for all regardless of location, wealth, or physical ability.

Terminology

AV - Autonomous Vehicle.

Frequent Service Area - The 1/4 mile area around a transit stop or the 1/2 mile area around a transit station where transit vehicles come, on average, every fifteen minutes for fifteen hours of the day and every thirty minutes for an additional five hours of the day, every day of the week.

Walkshed - The range of area within a five minute walk of a bus stop or a ten minute walk of a light rail, incline, or busway station.

LIDAR - Abbreviation for Light Detection and Ranging, a system that allows for autonomous vehicles to monitor their environment.

FLM - First/Last Mile problem, referring to the decline in ridership on public transportation as the distance required to walk to a bus stop or train station increases.

V2I, V2V - Vehicle to Infrastructure, Vehicle to Vehicle technology; technology that allows for communication between vehicles (both autonomous and non-autonomous) and infrastructure.

Smart City - Smart cities use information and communication technology to enhance livability, workability, and sustainability while addressing cities' growing demands of rapid urbanization and population growth.

Smartcards - Prepaid cards that allow for convenient access to multiple transportation services.

Smart Corridor - A fixed stretch of road with sensors and data connectivity that allow for testing of autonomous vehicles.

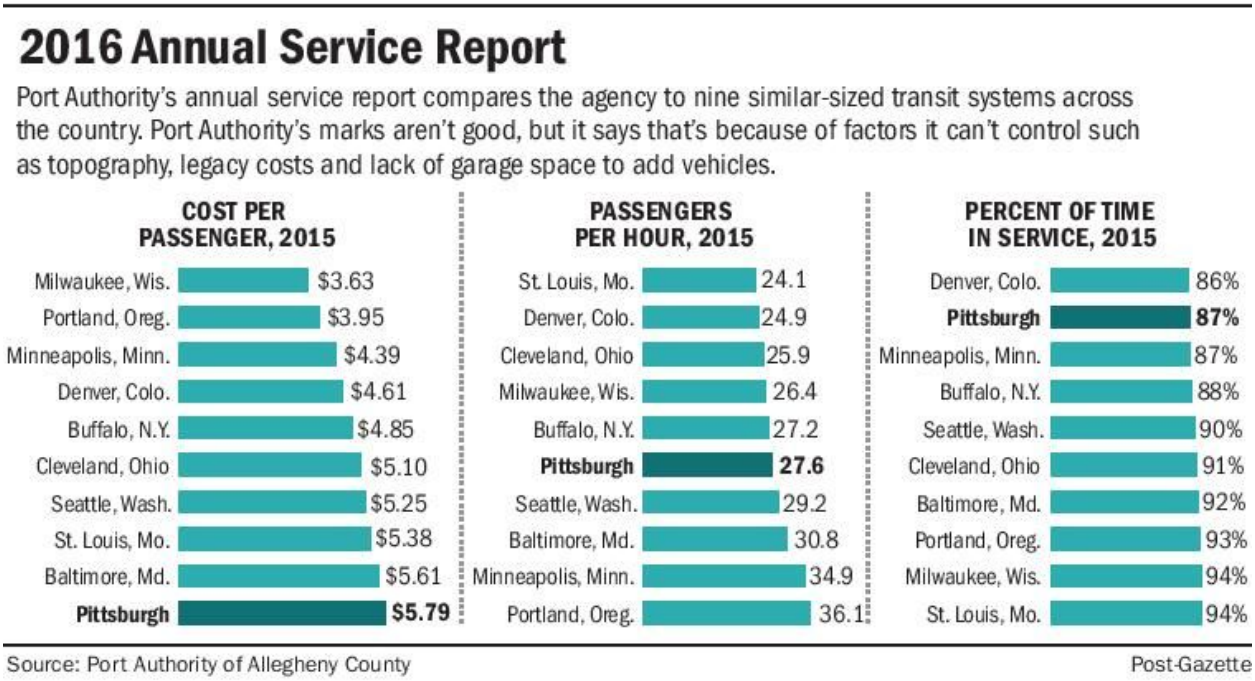
Current Public Transportation Landscape in Allegheny County

The current public transportation system in Allegheny County is, in many ways, inadequate and worsening. Many communities are underserved by public transit and require improved access to transportation. According to their 2016 Annual Service Report, the ultimate goals of Port Authority are efficiency, effectiveness, and equity. Efficiency is achieved by maximizing the number of outputs (passenger trips) while minimizing the number of inputs (time, vehicles, staff, etc.). Effectiveness is achieved through maximizing resident's access to and options for transit in order to grow ridership and promote long-term viability. Equity is achieved through improving mobility for those with the greatest need by providing targeted and representative service to specific populations within Allegheny County, such as those without access to vehicles or with limited incomes.[6]

These goals can be measured by "cost per passenger," "passengers per hour," and "percent of time in service." According to the 2016 Port Authority Annual Report, however, Port Authority is lagging behind other comparable agencies across the country. The report compares Port Authority to nine other similar agencies from various cities, including Milwaukee, Portland, Minneapolis, Denver, Buffalo, Cleveland, Seattle, St. Louis, and Baltimore. Port Authority is rated the lowest in terms of cost per passenger, the second worst in percent of time in service, and falls middle of the pack in passengers per hour.[7] The data provided from the report is illustrated in Figure 1, below.

[6] Port Authority of Allegheny County, *2016 Annual Service Report*, 2016, 3.
[7] Ibid., 7-12.

Figure 1[8]



In fact, Port Authority's middling position in comparison to other similar agencies is part of a larger trend for the agency. Passengers per revenue service hour has been decreasing since 2012 and cost per passenger served has been increasing since 2012.[9] Ridership has remained relatively constant after decreasing from 2007-2013[10], travel times remain high, the fleet size remains too small, bunching continues to be a problem, and overcrowding must be reduced. Overcrowding is especially a problem when the fleet is lacking in size and buses bunch. In fact, the number of overcrowded trips increased by 13% in 2016 alone.[11]

[8] Blazina, Ed. "Port Authority Service Continues to Have High Costs." *Pittsburgh Post Gazette*. 28 May 2017. http://www.post-gazette.com/news/transportation/2017/05/29/Port-Authority-service-pittsburgh-bus-cost-per-passenger/stories/201705290004

[9] Port Authority of Allegheny County, *op. cit.,* 7-8. note 6.

[10] Ibid.

[11] Ibid., 12.

Many of the issues with the current Port Authority system stem from service cuts that took place over the past decade. The Pennsylvania state government has repeatedly shown a willingness to cut the Port Authority budget, and in turn these cuts severely damage the public transit system in Allegheny County. In 2007, while the state was facing a large deficit and reduced the transportation budget, Port Authority cut routes by 15%.[12] The service cut was accompanied by other cost saving measures including freezing the salaries of senior staff, restricting benefits and pension plans, and reducing the overall staff.

In 2011, Port Authority experienced another series of cuts. Again, in response to state level cuts to the transportation budget, Port Authority was forced to institute service cuts. Initial plans were to cut 35% of routes, totaling 45 routes out of the approximately 130 total routes. Eventually, emergency funding allowed Port Authority to cut its service by only 13%.[13] These service cuts left some neighborhoods without service, increased fares, and prevented Port Authority from providing as effective of service to the public.[14]

In 2013, Act 89 brought some stability to Port Authority's financial status. Act 89 was passed in November of 2013 as a comprehensive transportation plan meant to improve transportation funding and infrastructure within the state. By year five of the plan, Act 89 plans to invest an additional $2.3-2.4 billion in transportation.[15] This increase in funding helped to reduce overcrowding and improve on-time performance.[16]

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[12] Ibid., 6.
[13] Ibid.
[14] "Port Authority to Cut Many More Routes, Raise Fares." *WTAE*. 22 June 2012. http://www.wtae.com/article/port-authority-to-cut-many-more-routes-raise-fares/7457137
[15] "ACT 89 Transportation Plan." *Pennsylvania Department of Transportation*. http://www.penndot.gov/about-us/Pages/Act-89-Funding-Plan.aspx
[16] Port Authority of Allegheny County, *op. cit.* note 6.

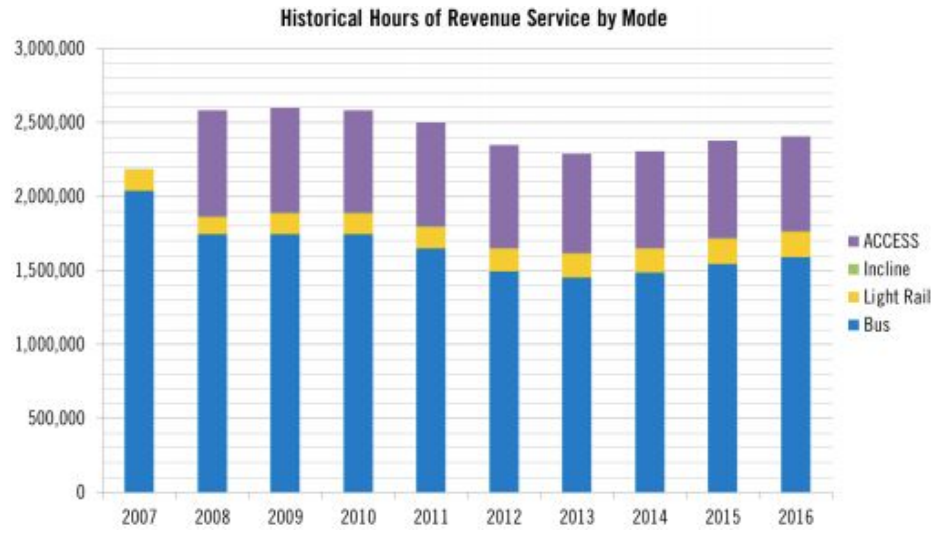
Port Authority's changes in funding, fleet size, employee size, etc. are summarized in Table 1(below).

Table 1[17]

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Service Area Sq Miles	775	775	775	775	775	775	775	775
Employees	3,269	3,249	3,327	2,876	2,833	2,783	2,784	2,920
Fleet Size	1,356	1,391	1,333	1,231	1,170	1,170	1,183	1,203
% Population 65+	17.80%	17.80%	17.80%	17.80%	16.80%	16.80%	16.80%	16.80%
Operating Funds (000's)	334,984	334,984	341,243	342,273	335,124	336,468	345,168	355,636

The data reflects the funding changes seen in 2007, 2010, and 2013. There is a general downward trend in both fleet size and total employees within the agency from 2007 to 2013. Following 2013, the operating funds begin to increase along with total employees and fleet size. The effect of the increase in total employees and fleet size on service levels is reflected in Figure 2 (next page). The number of service hours per year was decreasing from 2007 to 2013, but following 2013 a slight growth can be seen.

Figure 2[18]



[17] The data from the table was taken from the PennDOT Annual Service Reports from 2007-2015. The citation for the 2014-2015 report is below:
Pennsylvania Department of Transportation, *2014-2015 Annual Service Report*, 2015, 66.
[18] Port Authority of Allegheny County, *op. cit.,* 6. note 6.

Since 2013, the point at which service provided was the lowest, service has increased to its current level of 2,404,917 revenue vehicle hours per fiscal year. This reflects a 5% total increase in service level since the passage of Act 89 in 2013.[19]

Despite these gradual service level increases, Port Authority has seen a substantial decrease in its walkshed. The walkshed includes anywhere within a five minute walk of a bus stop or a ten minute walk of a light rail, incline, or busway station. Since 2007, Port Authority has lost a significant portion of its walkable service area. Only slightly more than 11% of the county is walkable to transit service on any day of the week, but the walkshed still serves approximately 35% of residents and 51% of the jobs due to population and job density.[20]

When evaluating the effectiveness of a transportation system it is also important to consider the frequency at which transit arrives. Having access to transit services is vital to the maintenance of a satisfying and comfortable life, but having access to transit without having to schedule one's day around transit schedules promotes additional mobility and is even more freeing to residents. According to Port Authority, a frequent service area is the 1/4 mile area around a transit stop or the 1/2 mile area around a transit station where transit vehicles come, on average, every fifteen minutes for fifteen hours of the day and every thirty minutes for an additional five hours of the day, every day of the week. Port Authority's frequent service areas cover 19% of residents in Allegheny County and 38% of the jobs.[21] This means that many people and many places of employment do not enjoy easy access to frequent service.

The proposed cuts in state funding would further damage the transportation landscape in Allegheny County. A budget proposal in the PA state legislature would reduce the Port Authority

[19] Ibid.
[20] Ibid., 9.
[21] Ibid.

budget by more than $80 million in this fiscal year.[22] As a result, Port Authority would be forced to make service cuts even larger than those experienced in 2007 and 2010. This could result in the elimination of half of the existing routes in Allegheny County.[23] While Governor Wolf stated that he strongly opposes this proposed policy,[24] the recent budget proposals illustrate a willingness among state representatives to cut transportation funding. Residents and local politicians should strongly consider the possibility of future budget cuts, as they would have devastating effects on those who rely on public transportation.

Furthermore, cuts to transportation contribute to a vicious cycle. Cuts to public transportation lead to fewer buses, longer walks to stops for riders, longer waits for riders, higher fares, and a less pleasant user experience. As a result, people are discouraged from using the public transportation system and may stop using it all together. This may lead to a further reduction in revenues for the agency, forcing the agency to make further cuts. This leads to a less effective and less frequently used transportation system. The lack of access to adequate transportation results in a reduction of the quality of life of residents.

There are three primary groups in Allegheny County in need of improved access to transportation. The first is the elderly (i.e. people 65 and older). This group represents a significant portion of both the County and City populations. Within Allegheny County, the

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[22] Blazina, Ed. "Port Authority Urges PA Legislators to Spare Public Transit From Funding Cuts." *Pittsburgh Post Gazette*. 11 September 2017.
http://www.post-gazette.com/news/transportation/2017/09/11/Port-Authority-Pittsburgh-Pennsylvania-Legislature-budget-public-transit-funding-cuts/stories/201709110177

[23] Mayo, Bob. "Port Authority Says Riders Could Face Massive Service Cuts Under Proposal Floated by Some PA House Members." *WTAE*. 11 September 2017.
http://www.wtae.com/article/state-budget-proposal-would-reduce-funding-for-public-transportation-force-cuts-for-port-authority/12221730

[24] Blazina, Ed and Liz Navratil. "Wolf Won't Transfer Money from Transit Trust." *Pittsburgh Post Gazette*. 09 November 2017.
http://www.post-gazette.com/news/transportation/2017/11/09/gov-tom-wolf-transit-fund-pennsylvania-budget-transfer-300-million/stories/201711090187

elderly make up approximately 18% of the population,[25] and 13.8% of the City population.[26] This is a large number of people who, upon reaching a certain stage in their lives, will be unable to drive. As a result, their mobility depends heavily on access to public transportation.

The second main group are those with physical disabilities. Individuals whose disabilities prevent them from operating a vehicle are particularly reliant on public transit, so shortcomings of the public transportation system are particularly damaging to them. In some cases, an individual's disability prevents them from being able to utilize standard public transportation systems. Either their disability completely prevents them from being able to access and ride buses, or it is such an inconvenience that riding the bus is impractical. Within Allegheny County 8.8% of the population is under 65 and physically disabled,[27] and within the City 10.2% of the population is under 65 and physically disabled.[28]

Port Authority currently provides additional access for both of these groups through the paratransit program ACCESS. ACCESS provides door-to-door, advance reservation, shared ride service for both the elderly and disabled. The ACCESS paratransit service was added to Port Authority in 2008, and currently provides services 7 days a week from 6 A.M. to midnight.[29] However, the ACCESS system has struggled to attract drivers and the service has suffered. Due to a lack of drivers, there are long wait times and frequent inability to schedule rides. Residents who wish to use ACCESS must request a ride at least a day in advance, but even then may still have their request denied. In September of 2016, for example, there were 141,000 one-way trips

[25] "Quick Facts: Allegheny County, Pennsylvania," U.S. Census, 2016, accessed 13 October 2017, https://www.census.gov/quickfacts/fact/table/alleghenycountypennsylvania/PST045216.
[26] "Quick Facts: Pittsburgh city, Pennsylvania," U.S. Census, 2016, accessed 13 October 2017, https://www.census.gov/quickfacts/fact/table/pittsburghcitypennsylvania/IPE120216
[27] "Quick Facts: Allegheny County, Pennsylvania," *op cit.* note 25
[28] "Quick Facts: Pittsburgh city, Pennsylvania," *op cit.* note 26.
[29] Port Authority of Allegheny County, *op. cit.,* 6, note 6.

scheduled and 1,050 trip requests turned down.[30] Many of those who have their request denied are trapped in their homes as a result and are unable to perform simple daily tasks like visiting the bank or the doctor.

The third group that is potentially impacted by a lack of access to transportation is urban communities. Upon further investigation, however, these groups are not significantly affected by a lack of transportation. Areas of concentrated poverty within the city of Pittsburgh are actually well located within the walkshed and frequent service areas. While urban communities face challenges related to overcrowding and bus arrival times, urban communities are not nearly as in need of access to public transportation as suburban communities.

The fourth group in greatest need of improved access to public transportation are residents of inner-ring suburban communities in Allegheny County. These communities are unique in that they do not have appropriate access to public transportation for their general needs, be they training programs, higher paying jobs, grocery stores, or health care facilities. Suburban communities are particularly vulnerable to public transportation budget cuts because they fall at the end of bus lines, which are often the least profitable for public transportation agencies. This is because the density of riders is often much lower in these areas. When transportation agencies face budget deficits, they are more likely to cut services at the ends of lines.

[30] Walton, Michael. "Port Authority's ACCESS Van Program For Disabled, Elderly Lacking Drivers." *Pittsburgh Tribune Review*. 03 October 2016. http://triblive.com/news/allegheny/11248610-74/access-county-drivers

Figure 3[31]

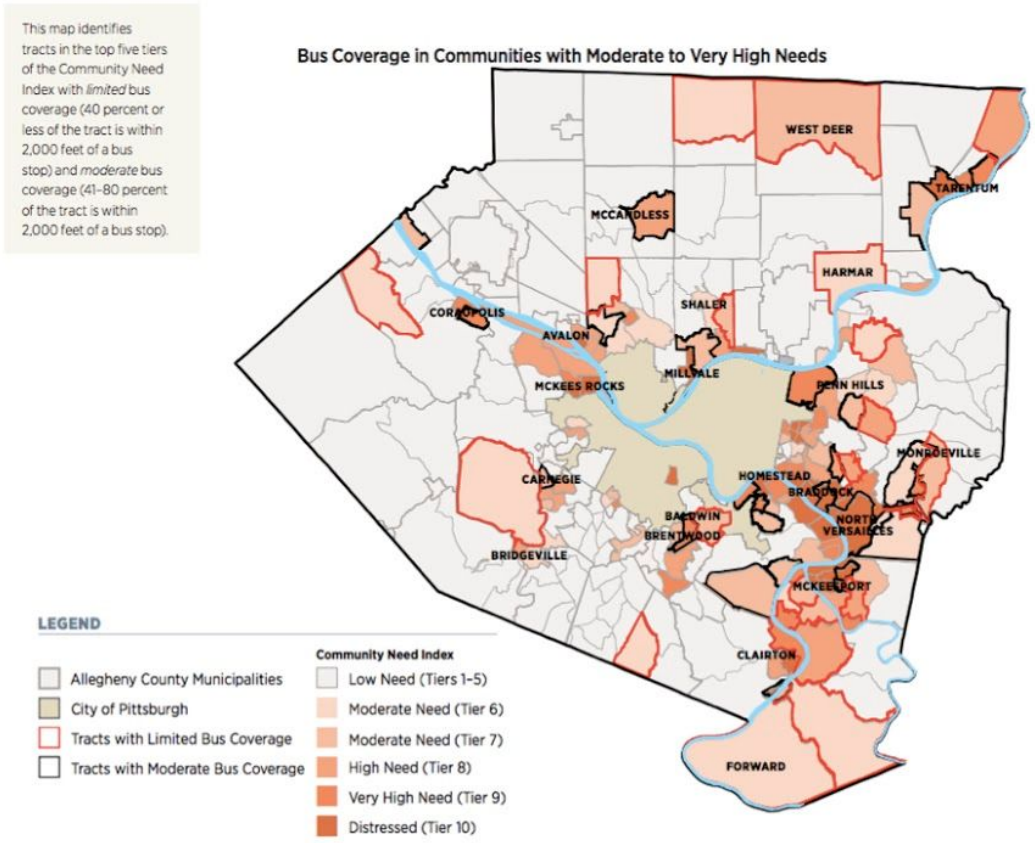

Figure 3 (above) depicts current bus coverage within specific suburban communities. One should note that this study only considers communities in Allegheny County outside of the City of Pittsburgh. A report conducted by the Allegheny County Department of Human Services states that 36% of suburban communities experience limited access to transportation while only 2% of communities experience limited access to transportation in the city limits.[32] Therefore, Allegheny County's suburban communities suffer from very clear instances of a lack of transportation in comparison to communities within city limits.

[31] Good, Megan, Kathryn Collins, & Erin Dalton, "Suburban Poverty: Assessing Community Need Outside the Central City," *The Allegheny County Department of Human Services*, 2014, 18.
[32] Ibid., 17.

Many suburban communities experience a "First/Last Mile" (FLM) problem. When residents live in areas with transportation budget cuts, they often experience difficulty getting from their homes to public transit stops, making the first and last miles of their trips particularly difficult. Most people are comfortable walking a distance of a quarter of a mile or less. Once the distance from their home to a transit stop exceeds a quarter of a mile, it becomes a burden to walk to public transit stops. This problem is exacerbated when people travel with groceries or children. As a result, the FLM problem discourages people from using public transportation.

Although elderly, disabled, and suburban residents suffer from a lack of access to public transportation, this report will focus primarily on how AV technology can benefit the lives of suburban communities. Given the ACCESS program's shortcomings related to a shortage of drivers, AV technology offers a unique opportunity to improve the service. The implementation of driverless ACCESS shuttles would alleviate scheduling and timing issues since human drivers would not be needed. Transportation related issues affecting suburban communities prove to be more complex than those faced by elderly and disabled populations, requiring more attention from policymakers.

Case Study: Duquesne, PA

Duquesne, PA, which is located in southeastern Allegheny County, is an example of an inner-ring suburb that struggles with suburban poverty and a lack of access to public transit. Many social issues in Duquesne could be solved with better access to transportation.

Duquesne's economic landscape was heavily reliant upon the success of Duquesne Steel Works, a steel plant that was in operation from 1886 to 1984.[33] The city reaped many economic benefits from the steel industry, employing roughly 8,000 people in the plant itself in 1948.[34] The population of Duquesne was highest in 1930, being home to roughly 21,000 residents.[35] Like many towns in the Pittsburgh area during the late 20th century, Duquesne experienced a period of rapid deindustrialization that drastically changed the community.[36]

Today, Duquesne residents face many challenges related to poverty. According to the U.S. Census, there has been a population decrease of 0.9% from 2010 to 2016.[37] 89.3% of residents 25 years and older have a high school degree or higher, while only 12.6% of the same population has a Bachelor's degree or higher. According to mayor-elect Nickole Nesby, Duquesne residents have experienced roughly four generations of illiteracy.[38] In addition, 80% of residents are recipients of Temporary Assistance for Needy Families benefits (TANF), a program designed to help families become more economically self-sufficient.[39] 40% of these residents have criminal backgrounds.[40] 55.7% of Duquesne residents ages 16 and older are in the civilian labor force while 9.3% of the population under 65 does not have health insurance.[41]

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[33] "Duquesne Steel Works," *Explore PA History*, 2003, accessed 10 December 2017, https://web.archive.org/web/20080521033853/http://explorepahistory.com/hmarker.php?markerId=788.
[34] Ibid.
[35] Ibid.
[36] Ibid.
[37] "Quick Facts: Duquesne city, Pennsylvania," *U.S. Census*, 2016, accessed 10 December 2017, https://www.census.gov/quickfacts/fact/table/duquesnecitypennsylvania/INC110216.
[38] Nickole Nesby, phone interview by Ian Asenjo, 27 October 2017.
[39] "Temporary Assistance for Needy Families (TANF)," Office of Family Assistance, accessed 10 December 2017, https://www.acf.hhs.gov/ofa/programs/tanf.
[40] Nesby, *op cit.,* note 38.
[41] "Quick Facts: Duquesne city, Pennsylvania," *op cit.,* note 37.

There is no immediate healthcare provider in Duquesne.[42] For families without access to a car and dependent on public transportation, accessing a healthcare provider can mean long waits and inconvenient bus stops, requiring residents to walk long distances before they reach their destination, assuming the family would be willing the make the visit in the first place. Many residents are limited to job opportunities nearby given the inconvenience and expense of the current bus system, thereby preventing them from pursuing employment with higher wages that might be located in the city of Pittsburgh or elsewhere. Residents must travel to McKeesport to access specific job training programs that may enable them to access employment opportunities as well.

Many of the bus stops within Duquesne are at inconvenient locations, requiring residents to walk long distances, often uphill, in order to arrive at the bus stop.[43] Lack of access to transportation very clearly prevents members of Duquesne from carrying out their daily lives. Since residents are also unable to access better employment because of a lack of access to transportation, those living under the poverty line experience great difficulty improving their socio-economic status.

Lack of reliable access to transportation also has psychological impacts on residents. Many residents of Duquesne attribute the low morale in their community to the difficulties presented by lack of access to transportation. Common errands that may seem trivial, such as traveling to the grocery store or the doctor's office, can prove to be a multiple hour ordeal, damaging residents' confidence in their ability to provide for their families and improve their well-being. "The day to day stuff…that are like a minor worry to someone else, really can affect

[42] Nesby, *op cit.,* note 1.
[43] Ibid.

someone emotionally, how they eat, everything...it has an effect psychologically…people just figure why bother."[44] This emotional struggle is also generational: "children see their parents and their grandparents feeling this way, and then it's like there's no hope."[45] The challenges associated with access to transportation in Duquesne have a clear link to the perpetuation of poverty and lack of motivation to pursue better lives.

In one particularly poignant example, Duquesne contains a housing complex called Hilltop Parkview Manor Apartments. The housing complex is home to approximately 600 residents who struggle to access the nearest bus stop. Mayor-elect Nesby describes the path to the bus stop as dangerous for residents: "it's not well lit, they're walking on the side of the street with no sidewalks and multiple children."[46] Lack of transportation not only limits opportunities to these residents, but endangers their lives as well since many roads leading to bus stops do not have proper sidewalks or streetlights. Secretary of the Democratic Committee of Duquesne and resident, Estelle Schumacher, explains these dangers, "they are forced to put their lives on the line just going out the door. And it shouldn't be that way. There should be buses that go up to areas where there are hundreds of people living."[47] Bus stops and access to public transportation should ideally be in close proximity to large housing complexes like Hilltop Parkview Manor Apartments, but when they are not, people are forced to resort to inconvenient and dangerous means to carry out their day.

[44] Estelle Schumacher, interview by Ian Asenjo and Zac Ettensohn, 03 November 2017.
[45] Ibid.
[46] Nesby, *op cit.,* note 1.
[47] Estelle Schumacher, *op cit.,* note 44.

Importance of Equitable Access

Access to transportation is vital to the ability to live a good life. Transportation mediates access to employment, healthcare, grocery stores, childcare, and banking among other life necessities. Without access to these things, individuals are unable to improve their positions in life. Without the ability to travel outside of their local communities, individuals are isolated socially and politically. Moreover, lack of access to transportation is often correlated with high levels of poverty, compounding need by placing access to needed jobs and services out of reach.

Research conducted by the Allegheny County Department of Human Services used specific indicators to determine which communities in Allegheny County are in greatest need of social services. These indicators include "Percentage of population 200% below the poverty line," "Percentage of families headed by single females," and "Percentage of households with no available vehicle," among many others. Communities with a high Community Need Index are found across all of Allegheny County, but inner ring communities on the edge of the city and along the rivers demonstrate a very high concentration of need. In these distressed areas such as Penn Hills and Braddock, 59% of residents, on average, are 200% below the poverty line with 45% of working age males unemployed.[48] Due to the lack of accessible transit, residents of inner ring suburbs experience longer commute times to life necessities. Studies have demonstrated the negative impact of longer commutes on life outcomes for children from low-income families. Those who live longer in high poverty are more likely to experience longer commute times, and over time fall farther behind on average income earnings.[49]

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[48] Megan Good, Kathryn Collins PhD., and Erin Dalton, "Suburban Poverty: Assessing Community Need Outside the Central City." *Allegheny County Department of Human Services* (August 2014) 7-9.
[49] Chetty, Raj, and Nathaniel Hendren, "The impacts of neighborhoods on intergenerational mobility: Childhood exposure effects and county-level estimates." *Harvard University and NBER* (2015): 67-78.

The City of Pittsburgh and Allegheny County have an obligation to provide an equal opportunity to all citizens to succeed in life. Currently, there are large populations within the county that do not have access to opportunities specifically due to a lack of access to transportation. It is important to recognize the booming technology industry's potential to exacerbate this increasingly inequitable situation.

Over the last few years, Pittsburgh's professional business and services sector comprised of tech companies like Google and Uber grew 3.7 percent.[50] Uber's Advanced Technologies Center alone added an estimated 380 jobs since it opened in April of 2016.[51] The influx of highly skilled, highly paid technological jobs has greatly contributed to the rapid increase in median home and rental prices in what were previously affordable areas. Neighborhoods such as Lawrenceville experienced double digit appreciation in property values over the past few years as a result of their attractiveness to the young tech professional market.[52] Over the last decade, median gross rent in Lawrenceville has increased by roughly 40%.[53] The trend of rising median gross rent is consistent across the city, extending to other previously affordable neighborhoods such as Bloomfield and East Liberty.[54] As these neighborhoods increase in cost, low-income-earning residents are forced to move outwards to more affordable communities in the inner ring suburbs. However, these communities, such as Duquesne, lack adequate access to

[50] U.S. Department of Housing and Urban Development. *Comprehensive Housing Market Analysis: Pittsburgh, PA.* Office of Policy Development and Research. (2016) 4.
[51] Ibid., 5.
[52] Tim Grant, "Up-and-coming Neighborhoods saw Home Prices Explode in 2016." *Pittsburgh Post-Gazette.* 27 February 2017, accessed 11 December 2017, http://www.post-gazette.com/business/money/2017/02/27/House-prices-rise-above-average-in-three-city-neighborhoods/stories/201702260031.
[53] *City of Pittsburgh Housing Need Assessment*, Mullin, Lonergan & Associates, Brean & Associates, and Fourth Economy, (2016) 23.
[54] Ibid.

transportation. Therefore, as residents are driven out, the potential for worsening their standard of living and restricting their access to opportunities increases.

The lack of adequate transportation directly impedes Pittsburgh and Allegheny county residents' ability to attain the equitable opportunities that the city seeks to provide. Pittsburgh's growing technological industry sector challenges the city's ability to adhere to its egalitarian maxim of "It's not for all; it's not for us."[55] Residents across varying levels of income are experiencing inequity of opportunity due to changes in the accessibility of transit.

The next wave of Pittsburgh's technological boom is already here. The influx of AV technology companies operating within the city have the potential to further disrupt the transportation system. The proliferation of AV operations not only has the potential to exacerbate the established trend of gentrification among Pittsburgh's affordable communities, but AV also stands to compete with transit ridership. Decreases in ridership will likely put a strain on the ends of bus routes, potentially leading to more bus line cuts, which would ultimately lead to even less access to transportation for the communities in the inner ring suburbs that need it the most. As these the changes start to occur, the city should prioritize interventions intended to protect these communities that stand to be harmed the most. To mitigate the potential negative impact of AVs, the city must find ways to leverage the benefits of AV technology to serve these communities first.

[55] City of Pittsburgh, "SmartPGH: If it's not for all; it's not for us," *US Department of Transportation*, 69.

How Past Transportation Innovations Have Impacted Pittsburg

The history of how Pittsburgh has dealt with past transportation innovations highlights lessons that can be applied to AVs.

The Streetcar

The streetcar first came to Pittsburgh in 1859. The implementation of the streetcar built upon existing lines put in place for the horse drawn omnibus.[56] Streetcars contributed significantly to the growth of Pittsburgh. Through the expansion of streetcar lines, more people were able to travel in and around the city. The outward growth of streetcar lines helped the city expand and allowed people to live further away from their workplace.

The overall expansion of lines and increase in ridership in the late 19th century show Pittsburgh's growth at the time. In 1863, there were 16.35 miles of track which carried a yearly total of 3,960,009 passengers.[57] In 1889, these numbers increased to 55.85 total miles and a yearly total of 23,546,456 passengers.[58] As the city expanded, more people relied on the streetcar as a form of transportation to reach the downtown area.

The streetcar continued to evolve with the implementation of new technology. The new technology increased the efficiency of the streetcar, allowing it to travel at faster speeds than its horse pulled predecessor. Additionally, the cars could transport more people.[59] This added element of efficiency enabled more people to access the streetcar and use it as a mode of transportation.

[56] Dr. Joel Tarr, interview by Margaret Edwards and Jeremy Goldstein, 23 October 2017.
[57] Tarr, *op. cit.,* 7. note 2.
[58] Ibid.
[59] Ibid., 14.

With the growth and increase in efficiency of the streetcar, one would expect that this mode of transportation was available to all. However, this was not the case early on. For example, high fares were a barrier to the working class. The high cost of ridership during the early implementation of the streetcar meant that public transit was used primarily by middle-class white-collar workers, rather than the industrial working class.[60]

The Automobile

There is no record of when the automobile first came to Pittsburgh, but in 1910 there were 1,601 cars registered to people living in Allegheny County, and by 1930 that number had jumped to 205,905.[61] This rapid growth contributed to significant changes in the city.

The advent of the automobile contributed to some infrastructure concerns among city leaders. In 1909, prior to the boom of automobiles, Pittsburgh's Mayor George Guthrie commissioned a group of leaders to develop an outline for a Pittsburgh city plan.[62] Bion J. Arnold's report, "Report on the Pittsburgh Transportation Problem," provided solutions for improvement of transportation equipment, rerouting of roads, and better service.[63] A second report by Frederick Law Olmstead, Jr. titled "Pittsburgh: Main Thoroughfares and the Down Town District: Improvements Necessary to Meet the City's Present and Future Needs," presented solutions to congestion, which included recreating traffic patterns and the upgrading of main outlying thoroughfares.[64] In light of these reports, infrastructure improvements were made during the 1910s. Some of the changes made included the widening of streets, creation of new

[60] Ibid., 24.
[61] Ibid.
[62] Joel A. Tarr, Dr. Joel Tarr, *The Automobile and the "Smoky City": The Impact of the Motor Vehicle on Population Distribution, Building Patterns, Industrial Location, and CBD Traffic Patterns in Pittsburgh and Allegheny County, 1910-1930,* (Pittsburgh: Carnegie Mellon University, 1975), 5.
[63] Ibid., 6.
[64] Ibid.

highways and roads limited to certain forms of transportation, and reducing grades of hills.[65] Additional work occurred following World War I to accommodate the increased usage of automobiles.[66]

Automobile Infrastructure Community Impact

The wide-scale production and use of automobiles in the postwar United States necessitated new infrastructure like highways and parking lots so that the technology could be put to practical use. During the first Pittsburgh Renaissance of the late 1940s to the mid-1960s, urban renewal projects geared toward improving automobile accessibility harmed communities such as the Lower Hill District and East Liberty. The public-private partnerships of the Urban Redevelopment Authority (URA) and the Allegheny Conference on Community Development (ACCD) spearheaded urban renewal projects, but often did not adequately address the concerns of the city's lower income residents. Major construction projects cut off and disrupted vibrant, tight-knit communities where small businesses thrived. Large numbers of city residents were evicted to make way for new construction projects. In preparing Pittsburgh for the next transportation revolution that is the emergence of AVs, we must learn from past transportation infrastructure mistakes made in the Hill District and East Liberty to ensure that the wellbeing of lower income communities is not traded for the benefit of wealthier ones.

Urban Renewal Hits the Lower Hill

The building of the Civic Arena had major ramifications for the implementation of automobile infrastructure in the city. The private Pittsburgh Regional Planning Association (PRPA) found that Highland Park would be the best place to put an arena since it was not

[65] Ibid., 9.
[66] Ibid.

densely populated. This made it preferable as compared to neighborhoods like the Lower Hill District which would require the costly resettling of many residents. However, Highland Park residents raised fierce opposition to the plan over concerns that the arena would disrupt the peace of the community, lower property values, and hurt residential parking.[67] Mayor David L. Lawrence sought to avoid a difficult political and legal fight against wealthy Highland Park residents and decided to look elsewhere for an arena location.[68]

The ACCD pushed for the Lower Hill District to be cleared fearing that the perceived slum was threatening to halt the progress of urban renewal projects in the city. Deeming much of the housing in the Lower Hill District substandard and blighted, the ACCD argued that the area could be put to more prestigious and profitable use than the slum that it supposedly was. The ACCD also contended that by eliminating the blight in the Lower Hill, the rest of the Hill District could be rehabilitated by connecting it to the proposed cultural and business district that would replace the slum as a link between the Hill and downtown.[69] However, the elite organizations managed to overlook redeeming qualities of the vibrant community that may have been worth preserving through alternative solutions to outright demolition.[70]

Since the lower income residents of the Lower Hill had less political and economic capital than the ACCD or Highland Park residents, the city decided to allocate about one hundred acres of the Hill for the building of a new cultural district with an amphitheatre for the CLO and a convention center. Demolition began in 1956 and eventually displaced over 1,500 families and

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[67] Gregory J. Crowley, *The Politics of Place: Contentious Urban Redevelopment in Pittsburgh* (Pittsburgh: University of Pittsburgh Press, 2014), 59-61.
[68] Dan Fitzpatrick, "The Story of Urban Renewal," *The Pittsburgh Post-Gazette* (Pittsburgh, PA), 21 May 2000.
[69] Crowley, 80-82.
[70] Mindy Thompson Fullilove and Rodrick Wallace, "Serial Forced Displacement in American Cities, 1916–2010," *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 88, No. 3 (2011): 385-386.

400 businesses. In order to make the area accessible to the automobile, space was needed for parking lots and highways to reach the newly cleared area. The Civic Arena was the only structure to materialize in the area of the proposed cultural buildings and much of the cleared land remained as nothing but parking lots for decades.[71] The attempt at renewal ended up eliminating connecting roads between the rest of the city and the Hill while public transportation was cut and the installation of a major highway through the neighborhood deteriorated the quality of life for neighborhood residents. The failed urban renewal project in the Hill effectively destroyed the once vibrant community, causing the neighborhood to enter a long and painful period of decline over the next decades characterized by high crime rates and poverty against the backdrop of deindustrialization.[72]

Failed Urban Renewal in East Liberty

In the 1960s, the bigger businesses in East Liberty were concerned about increasing suburbanization and competition from shopping malls. In order to make the neighborhood's businesses more amenable to shoppers who drove and to alleviate heavy congestion in East Liberty, the URA hatched a plan to turn much of the neighborhood into a pedestrian mall with a loop road around it. At 254 acres, the URA proposed an East Liberty urban renewal area three quarters the size of downtown in the most ambitious renewal project attempted yet in the city.[73]

Numerous issues hampered the project. The rapid development of suburban malls and their relatively quick construction time outpaced the relevance of the East Liberty project. The designated parking areas that were part of the project design for freeing up the inner pedestrian

[71] Edward K. Muller, "Downtown Pittsburgh: Renaissance and Renewal," (University of Pittsburgh Press), 11.
[72] Fullilove and Thompson, 386-387.
[73] Justin P. Greenawalt, "Pittsburgh's East Liberty Project: Preserving the Artifacts of the Urban Renewal Era," Master's Thesis for Columbia University's Graduate School of Architecture, Planning, and Preservation, May 2010, 37-39.

mall meant that customers would have to walk blocks to get to certain stores, a concern that small business owners raised at the time, but was ignored. While the URA's project added an estimated 2,000 parking spots to East Liberty as many as 280 small businesses closed shop as six years of construction blocked consumer access to stores. The full efficacy of the renewal project in regard to utilizing the loop to divert automobiles around the pedestrian mall was based on expectations of heavier traffic as a result of a proposed state-funded highway connecting downtown to East Liberty. When the plan for the downtown to East Liberty highway fell through, the whole loop project was rendered somewhat irrelevant but by then had come at the cost of hurting the community and the neighborhood economy.[74] The failed urban renewal project in East Liberty serves as a cautionary tale not to assume that building infrastructure geared toward a specific mode of transportation like automobiles will guarantee that more people will come with their automobiles, especially given the risk of prolonged construction.

Takeaways

As Pittsburgh prepares itself for the not so distant future of AVs, we should look to the past for relevant lessons about how to properly implement new policies.

We must consider who imminent transportation changes will impact and how they will be impacted. Whether or not it is politically or legally easy, Pittsburgh must find ways to ensure that convenience for the rich is not prioritized over the lifeblood of lower income people. As streetcars gained popularity, only the wealthy reaped the full benefits despite the innovation being marketed as available to everyone, regardless of class. Since working class people were only able to ride the streetcar when they could afford it, they were prevented from fully partaking

[74] Dan Fitzpatrick, "East Liberty Then: Initial makeover had dismal results," *The Pittsburgh Post-Gazette* (Pittsburgh, PA), 23 May 2000.

in the benefit of the new technology. Take Pittsburgh's failed automobile-centric infrastructure projects as another example. The desire among the middle class and the wealthy to have a cultural district unencumbered by nearby slums and accessible to automobiles overruled the desires of the Hill District's generally lower income residents. While parking lots and highways in the Hill District made the Civic Arena and downtown more accessible to middle class drivers, the new infrastructure disrupted and harmed the community. Likewise, in East Liberty big businesses' interest in making the area more accessible to middle class drivers resulted in overly ambitious infrastructure projects that ultimately hurt smaller businesses and the community as a whole. By being more responsive to the concerns of lower income communities and being conscientious about how to implement infrastructure for AVs, Pittsburgh can avoid exacerbating inequities and possibly help fix them. The technology of AVs is distinct from prior innovations and Pittsburgh should take proactive steps to ensure that the technology is put to use to address the concerns of those who have been historically marginalized.

State of Autonomous Vehicles

Current

Autonomous capabilities have been steadily and increasingly implemented in consumer vehicles for a number of years. Low-level automated features such as Adaptive Cruise Control, Automatic Emergency Braking, and Lane Departure Warning have been in luxury automobiles for a few years and are starting to become commonplace in economy automobiles. Even these capabilities have been shown to significantly decrease the potential for accidents, which improves safety and traffic flow within cities. Vehicles with Advanced Driver Assistance

Systems (ADAS) such as Subaru's EyeSight Technology, which combines Adaptive Cruise Control, Automatic Emergency Braking, and Lane Departure Warning, were 60% less likely to be involved in accidents than those without it.[75] These low-automation developments demonstrate only one of the 5 levels of autonomy (Level 1), which progress as follows: Driver Assistance (Level 1); partial automation (Level 2); conditional automation (Level 3); high automation (Level 4); full automation (Level 5). Level 1 requires a human driver to drive, but specific functions such as accelerating can be automated.[76] Level 2 systems can allow a human driver to not steer or accelerate, but require the driver to be ready to intervene and take control at all times. In level 3 AVs, drivers can completely disengage from actively driving but only in specific driving conditions, such as on the highway. Drivers are still expected to be able to take control if needed, with some advance notice. Level 4 vehicles are essentially fully autonomous and drivers are not needed; however, the autonomy does not extend to all driving scenarios. For example, off-road driving may not be possible with a level 4 AV. Level 5 is the ultimate goal of AV researchers. Level 5 vehicles can be expected to respond to any driving scenario in much the same way as a human driver and would not even require a steering wheel to be placed in the vehicle. Currently, AVs such as the ones Uber and Tesla use on Pittsburgh streets are at level 2 partial automation, but many car companies boast plans to have fully autonomous vehicles by the early 2020s. Recently, Waymo, an affiliate of the Google-owned Alphabet company, has announced a level 4 vehicle on the road in Arizona, suggesting that this goal might be attainable sooner than previously expected.

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[75] SBD Automotive and HERE, "How autonomous vehicles could relieve or worsen traffic congestion," accessed 3 October 2017, https://www.sbdautomotive.com/en/autonomous-cars-traffic.

[76] Hope Reese, "Updated: Autonomous driving levels 0 to 5: Understanding the differences," TechRepublic, 20 January 2016, accessed 10 December 2017, https://www.techrepublic.com/article/autonomous-driving-levels-0-to-5-understanding-the-differences/.

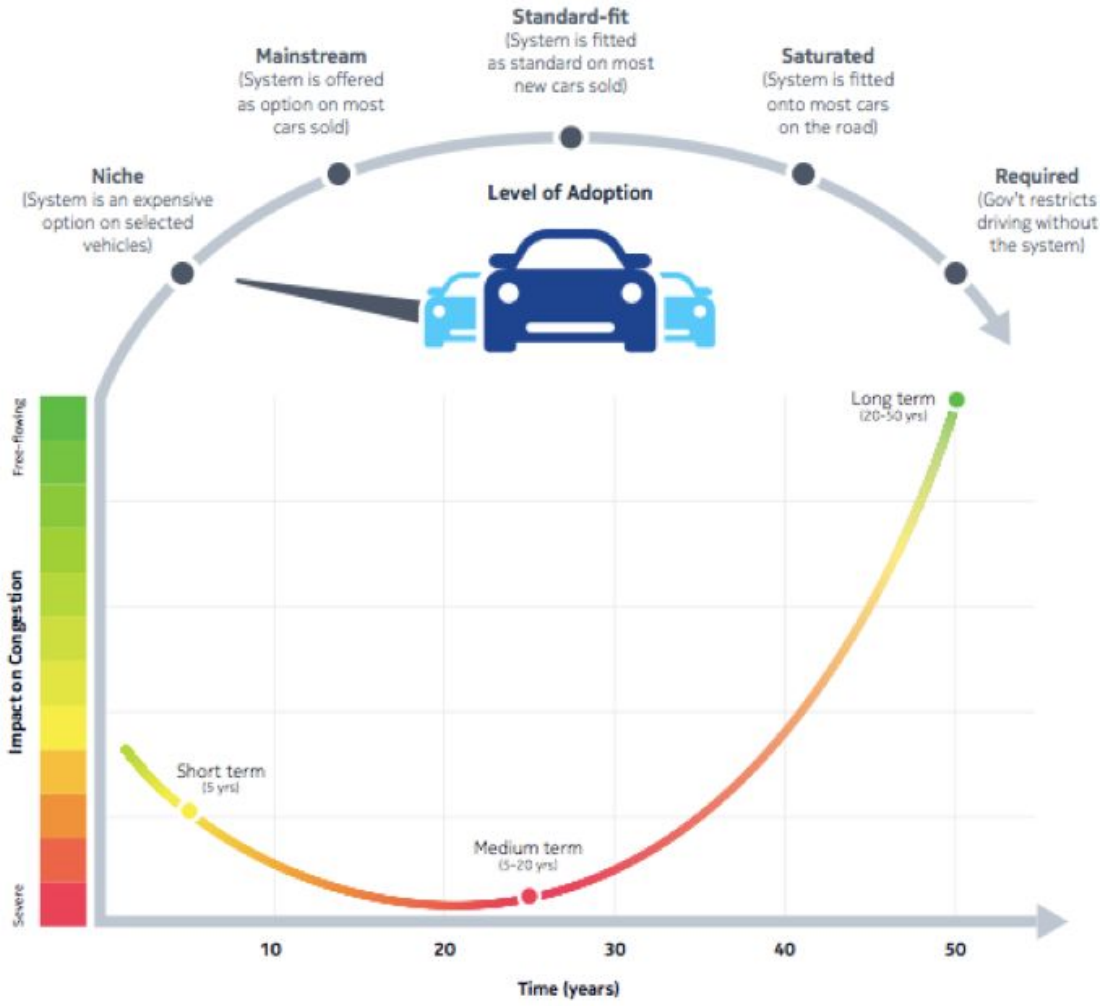
Near Future

The saturation of AVs on public roads is currently low. In the next five years, it is probable that full level 5 automation will be in its final development stages and begin integrating into ride-sharing services and some consumer vehicles. Market saturation of fully autonomous vehicles will only begin to increase in 10 to 15 years for personal vehicles through major car company developments and retrofitting technologies. Retro-fitting is the ability to install LIDAR systems, computers, and sensors to non-autonomous vehicles. When retro-fitting capability becomes reasonably affordable, this will open the door for a rapid increase in fully automated vehicles on American roads.

During the transition between low automation and fully automated cars, the impact of AVs can significantly vary depending on the number of such vehicles on the road. Initially, research shows benefits to traffic flow with a low saturation of level 4 and 5 AVs, but drivers might be surprised by the different behavior of computers behind the wheel, leading to more traffic and more frequent accidents. Figure 4 below depicts the level of risk associated with mixed integration of autonomous and non-autonomous vehicles.

Vehicle-to-Vehicle (V2V) technology can help mitigate many of these issues. V2V and Vehicle-to-Infrastructure (V2I) technology can help vehicles communicate with cars, traffic lights, ambulances, and potentially even bicyclists, and could help reduce the risk of the mixed AV and human driver scenario. V2V technology is under development by numerous companies and has already been implemented in certain vehicles. The concept has been endorsed by the federal government, and there are indications that V2V will be mandated in the near future.

Figure 4[77]



Many V2I features are also already available, but not yet widely deployed in Pittsburgh. Pittsburgh needs to prepare to offset the potential risks of mixed integration and unpredictable inter-road flows by implementing "Smart City" proposals and other improvements to infrastructure to maximize the safety and efficiency of the entire local transportation system.

[77] SBD Automotive and HERE, *op. cit.,* note 74.

Benefits of AVs

Pittsburgh has already taken many steps towards becoming an AV-friendly city, and should not reverse its course of actions. More so than most cities, Pittsburgh can already attest to the growing utility of AVs and the benefits that can be gleaned from being a hub of AV innovation. First, the potential for economic growth is incredible. An Intel report published earlier this year valuates the AV industry at $7 trillion by 2050.[78] This estimate represents the global industry, but the same report expects the industry to be worth $800 billion by 2035, and this industry is likely to be most prevalent in the United States, which is currently at the forefront of AV development. Pittsburgh in turn has the potential to become the center of American AV development. For instance, Argo AI launched its headquarters in Pittsburgh after a $1 billion investment by Ford, employing 200 local scientists and engineers, demonstrating that Pittsburgh is still in the forefront of the development of AV technology.

Additionally, Pittsburgh is home to Carnegie Mellon University, an institution that has been working on creating and perfecting autonomous technology for decades. Many of the world's leading experts on AVs work at CMU. CMU scientists, professors, and graduates have all worked closely with or founded companies such as Argo AI and Uber. CMU has a long history working with AV technology and winning the DARPA Grand Challenge was a huge milestone for its AV program. Furthermore, CMU has also worked closely with the City of Pittsburgh in the past for certain initiatives, such as the Smart City challenge most recently. All of these factors demonstrate not only CMU's willingness to help transform Pittsburgh into a

[78] Roger Lanctot, "Accelerating the Future: The Economic Impact of the Emerging Passenger Economy," Strategy Analytics and Intel, June 2017, accessed 10 December 2017, https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/05/passenger-economy.pdf.

center for AVs, but also the wealth of resources an AV company could access by coming to Pittsburgh.

In addition, widespread implementation of AVs has the potential to significantly improve traffic safety. Research by the National Highway Traffic Safety Administration (NHTSA) shows that "94% of serious crashes are due to dangerous choices or errors people make behind the wheel." Human error is by far the most important factor in vehicle accidents, but is an error that can be addressed substantially by AVs. In 2013, Pittsburgh saw 39 traffic fatalities, a number which could be substantially reduced if AVs were implemented. This is why the NHTSA is "committed to advancing [truly "self-driving" vehicles] in order to eliminate motor vehicle-related deaths on America's roads."[79]

AVs are capable of making general transportation in Pittsburgh more efficient by not only reducing accidents as mentioned above but also by shortening commute times. For example, AVs driving around other AVs do not need to leave as much space between cars, since the communications system (V2V) allows cars to know when to brake far quicker than human drivers could. Inefficiency caused by human driving could also be eliminated, aiding traffic in the often-choked tunnels of Pittsburgh. Squirrel Hill Tunnel, infamous for its ability to create a traffic jam even without many cars on the street, could see traffic flow through much quicker, decreasing commute times for riders. An AV-friendly city would see a decrease in common traffic issues such as gridlock by utilizing V2V and V2I technology, aiding efficiency of transportation as well.

[79] National Highway Traffic Safety Administration, "Automated Vehicles for Safety," accessed 10 December 2017, https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.

Lastly, AVs offer a unique opportunity for Pittsburgh to address some of its public transportation deficits, including those pertinent to underserved communities. AVs may offer cost savings over other improvements to public transportation infrastructure. And as infrastructure improvements are made, the city can make a conscious effort to prioritize AV-conscious improvements in underserved areas first. In this report, we offer several concrete proposals for how specific AV technologies can be utilized to supplement the public transportation system, and how those supplements can specifically target underserved areas.

The benefits of AVs are vast, from an economic and social standpoint to efficiency of transport, and are here to stay. In order to leverage the coming boom in AV technology and maximize the benefits to Pittsburgh, Pittsburgh needs to adopt and implement proposals that can make the city more AV-friendly which can also aid underserved communities. Given the incredible economic benefits that can accompany AV development and the presence of world class AV institutions already in Pittsburgh, the city should strive to continue to be a hub for AV innovation.

Lessons from History

The increasing prevalence of AVs will likely constitute the next transportation revolution. As our discussion of past transportation revolutions demonstrated, there are often negative consequences when new transportation modes are implemented despite the benefits of improved technology. As wealthier residents have historically sought to benefit from the convenience that new transportation technologies offered, lower income communities have seen the negative side effects of these new technologies. Fares for streetcars were often too costly for the working class.

Later on, the infrastructure needed to improve automobile access around the city for middle class drivers severely disrupted the Hill District and East Liberty while neighborhood residents did not benefit as much as they should have in terms of access to transportation. The recent technology industry boom in Pittsburgh has seen the process of gentrification force residents out of once affordable neighborhoods like Lawrenceville and East Liberty into inner ring suburbs that lack proper access to public transit. Since AVs are a distinct type of technology from past manned forms of transportation that required construction of new tracks or highways, the range of possibilities for how to implement the technology in the city is different from prior transportation innovations. AVs can address the concerns of underserved communities, improving on past transportation shifts that ran roughshod over low income communities just to improve convenience for wealthier residents. However, Pittsburgh must be proactive in its approach to AVs if the city is to address the concerns of lower income communities about transportation and to ensure that the technology is smoothly implemented.

Proposals

Our proposals fall into two categories. First, we explore the actual changes that should be made to public transportation itself through the use of AV technology such as shuttles. These changes are meant to improve the struggling public transportation system, particularly with regard to communities that are currently underserved. The second set of proposals establishes the measures that should be taken in order to continue to incentivize and prepare for the adoption of AV technology in Pittsburgh.

Autonomous Shuttles

Autonomous shuttles are one of the most intriguing and versatile technologies within the realm of AVs. Existing autonomous shuttles are electric, can carry 15 to 20 passengers, and are currently capable of navigating city streets autonomously.[80] Unlike autonomous cars, shuttles are able to drive along predetermined routes without the oversight of a driver. Other features tend to include intercoms and interior cameras. There are numerous companies committed to autonomous shuttle research and production, many of which have tested their vehicles in public spaces. Industry leaders include French companies NAVYA and EasyMile, Japan's SB Drive, and American companies Local Motors and Auro Robotics.[81]

Autonomous shuttles offer an excellent solution to the First/Last Mile (FLM) problem. Due to their autonomous capability and high occupancy, they can run along predetermined routes centered around bus stops, picking up passengers who otherwise would not be able to always walk to the stop. Evidence suggests that anyone who lives more than a quarter of a mile away from a bus stop is unlikely to use the bus. Shuttles could expand the range of a bus stop dramatically by connecting these people to their closest bus stops, making busing accessible for many more potential riders.

Our first proposal is that the city begin exploring partnerships with industry leading companies. Getting such organizations interested is eased by the fact that every autonomous shuttle company is jostling for the reputation of being the best in this emerging industry. The

[80] Pessaro, Brian, "Evaluation of Automated Vehicle Technology in Transit - 2016 Update," *National Center for Transit Research*, April 2016, accessed 10 December 2017.
[81] "5 Companies Working On Driverless Shuttles And Buses," CB Insights Research, 4 August 2017, accessed 4 December 2017, https://www.cbinsights.com/research/driverless-shuttle-companies/.

ability to offer a public platform for companies to showcase their technology is one of the city's best bargaining chips, and will help bring multiple autonomous shuttle companies to the table.

Furthermore, Pittsburgh can utilize a service similar to HART HyperLINK, a system established in Tampa that provides FLM transport.[82] The system allows users to use a smartphone app to call a car to their doorstep for very low prices which will then drop off the user to a bus stop based on when the bus is scheduled to arrive in order to alleviate the FLM problem and increase ridership efficiency. A system such as HART HyperLINK can be used to aid the FLM problems in underserved communities as a stop-gap measure to help while autonomous shuttles are implemented, but also to get data on how and where FLM solutions create an increase in ridership on existing public transportation. The data could then be used to identify areas where autonomous shuttles would be most effective.

We propose that three types of areas be targeted during the early stages of autonomous shuttle adoption. The first are areas where the FLM issue is a clear problem. Such neighborhoods are characterized by either a lack of bus stops or a high average distance of households from bus stops. Citizens in these areas can rightly be considered lacking with regard to public transportation. Installing shuttles to run predetermined routes in areas with low access would make public transportation a feasible option for many new households, increasing ridership and general accessibility.

Duquesne provides numerous examples of FLM problems. The Hilltop Parkview Manor Apartments are an extreme case, with no bus stops within easy walking distance. To overcome this issue, one of the first autonomous shuttles brought to Pittsburgh should be located at the

[82] "About HART," *HART Hyperlink*, accessed 10 December 2017, http://www.gohart.org/Pages/AboutUS-HART.aspx.

apartment complex. This shuttle could run a 20 to 30 minute loop from the apartment building to nearby bus stops, granting easy access to public transportation.

The second type of area that should be targeted are those with high levels of ridership across short distances. Examples of this are the Fifth and Forbes Ave. corridors near the University of Pittsburgh and Carnegie Mellon University. In such areas, there are populations that have a daily need to travel relatively short distances, and the buses are often filled with these short-range riders. A high number of buses is therefore necessary to accommodate both short and long distance riders. Plans have been proposed to establish a bus rapid transit corridor in Oakland, but there has been some resistance to the idea. In particular, many local residents are concerned that eliminating the familiar routes will make their commutes more difficult.[83] As an alternative, we propose that autonomous shuttle routes be established in these areas to provide transport for short-range riders. This should decrease the overall ridership on those particular bus routes, allowing one or more of those buses to be reallocated to areas currently suffering from an insufficient number of available buses while maintaining the familiar route system.

A final way that autonomous shuttles could be harnessed would be as short range transport in low-access communities. This is similar to the solution we propose for areas that have a large number of households outside the range of the bus stops, but in this instance the problem is a lack of short range transportation within the community. Getting to and from stores, parks, and public buildings within a neighborhood is difficult for people who live in areas with infrequent busing and few private cars. Rather than reroute an entire bus, simply adding a shuttle that drives a continuous loop throughout a neighborhood while stopping at key locations would

[83] Ed Blazina, "City's bus 'rapid transit' plan to extend past Oakland," *Pittsburgh Post Gazette*, 31 May 2017, http://www.post-gazette.com/local/city/2017/06/01/Bus-rapid-transit-pittsburgh-port-authority-public-transportation-pa/stories/201706010065.

address the problem just as well, with less cost and fewer complications. A single bus costs hundreds of thousands of dollars to own and operate, with about 70% of operating costs coming from wages and benefits to drivers.[84] An autonomous shuttle avoids these costs. Thus, we propose that areas with a clear lack of accessible public transport, coupled with a high need for short range travel, be identified, with a few being chosen as initial sites for implementing autonomous shuttles.

As an example, many residents of Duquesne prefer to do their grocery shopping at the Giant Eagle in the Kennywood Mall. This shopping center is a four minute drive away from Hilltop Parkview Manor Apartments, but is reachable only through one bus route, the 59. This bus runs infrequently, meaning that Duquesne residents can experience waits of up to an hour.[85] An autonomous shuttle could solve this problem by running a loop between densely populated areas in Duquesne and the Kennywood Mall. Duquesne residents would be provided with consistent transportation to the Mall, eliminating long wait times. This policy also would empower residents to access healthy food for themselves and their families, improving the morale in the community.

Buses

While there is much speculation regarding the long-term viability of buses as a means of public transit, it is clear that for the foreseeable future buses will remain the most effective method to transport large numbers of people. This means that all of the problems that plague the Port Authority, such as driver pensions, monies paid for damages, and inefficiency, are going to continue. Many of these problems could be alleviated, or even eliminated, through the adoption

[84] Christopher MacKechnie, "How Much Does a Bus Cost to Purchase and Operate?" *Thoughtco,* 10 July 2017, accessed 04 December 4 2017, https://www.thoughtco.com/bus-cost-to-purchase-and-operate-2798845.
[85] Nesby, *op. cit.,* note 1.

of AV technology on public buses. The technology is already available, as it is the same technology that is used by autonomous cars and shuttles. Other cities have installed autonomous technology on public buses with great success. For example, in 2016 Washington's state transit agency Pierce Transit equipped seven buses with an AV technology called Mobileye.[86] These buses were found to be far less accident prone, to the degree that the Federal Transit Authority awarded a grant to allow Pierce Transit to upgrade the entire fleet with the technology.

Given the availability of this technology, we propose that the Port Authority take a proactive approach to equipping buses with AV sensors and software. Partnering with one of the many AV leaders in Pittsburgh, the Port Authority should set aside a few buses to equip and test. If successful, the city can then search for grants from government organizations such as the Federal Transit Authority in order to equip the rest of the fleet. The equipment may be somewhat expensive, but giving companies the opportunity to showcase their technology and form a working relationship with Port Authority should be enough to create an environment of cooperation. In the long run, these upgrades should reduce costs from collisions and fuel consumption. This will make Port Authority, an organization plagued by financial problems, better able to survive budget cuts and thus preserve access to public transportation in Pittsburgh.

Smartcards

The past few years have seen a gradual shift away from actual payment of money upon entering a public bus towards "smart card" systems. These cards allow for faster, easier payment of fares and are utilized by most riders. With the advent of ridesharing services, however, smartcards have run into a problem. Ridesharing services are not covered by a smartcard, and so

[86] "Pierce Transit receives $1.66 million grant to install bus safety technology," *Suburban Times*, 22 January 2017, https://thesubtimes.com/2017/01/22/pierce-transit-receives-1-66-million-grant-to-install-bus-safety-technology/.

a rider who is using both a bus and a rideshare service still ends up paying a significant amount of money for travel. This is especially harmful in instances where a person is granted subsidized bus fare from the city or state, yet must pay ridesharing costs out of their own pocket. Once shuttles are adopted, public transportation will be comprised of a variety of transport options instead of just busing. Ideally, a single card could be used across all these potential transportation options, with consistent price models that would take existing subsidy programs into account and prevent ridesharing costs from becoming prohibitive.

Solutions to this problem have already been investigated, with various cities trying out different methods. For instance, Nashville recently began exploring a way to link smartcards for city buses with private rideshare services, with a single account being used for both public and private transportation.[87] Systems such as this make transitioning from one form of transport to another easy, while allowing existing transportation subsidies to be applied to rideshare or shuttle services as needed.

We believe that the city should immediately begin investigating different methods for streamlining transitions between public and private transport through smartcards. Different approaches will have different demands on the city's resources, but overall a smartcard system that allows for a rider to move seamlessly between transportation types is the best solution. Creating this new system will likely take some time to design, especially as ridesharing becomes more prevalent. Thus it is best to begin discussing this problem now, rather than when differing price models have begun to gouge riders. Without an effective smartcard system, transportation

[87] Joey Garrison, "Nashville explores linking Uber, Lyft to Metro bus system," *Tennessean*, 28 March 2016 .http://www.tennessean.com/story/news/2016/03/28/metro-explores-linking-uber-lyft-bus-system/82336598/.

will become technically accessible, but not affordable, to many riders and transportation inequity will continue.

Infrastructure Developments to Prepare for Autonomous Vehicles

In order to harness AV technologies to help address the needs of underserved areas, Pittsburgh must first ensure that AV companies continue to find the city an attractive place to expand their research and development. As the Smart City Challenge demonstrated, an effective way to incentivize more companies to come to Pittsburgh is by creating more unique infrastructure opportunities within Pittsburgh. More places to test AV technology generates more interest by AV companies. Furthermore, specific underserved communities and well-served citizens alike will benefit from increased mobility through better access to Pittsburgh's transportation system. Transitioning to an AV-friendly transportation system means focusing on developing the "Smart City."

Smart Cities and Connectivity

Smart cities use information and communication technology to enhance livability, workability, and sustainability while addressing cities' growing demands of rapid urbanization and population growth. A smart city builds on the relationship between the city's responsibilities to its citizens and the smart technologies that enable their completion.

One of the most important aspects of a Smart City for AV transportation is connectivity, which is how Smart City technologies are networked together with each other and a control center. AV technology on its own is much less valuable without the necessary infrastructure to improve the functionality and safety of these vehicles through communication. Smart City

infrastructure is in many ways more important than the AVs themselves, and the private-sector is already preparing for a future where this infrastructure is an integral part of any city.

Lane Markings

Clear and bright lane marking has been shown to help reduce accidents amongst human drivers, but as AVs become increasingly prevalent, lane marking takes on added importance. The camera and LIDAR systems onboard an AV rely on clear lane marking to ensure the car knows its boundaries and as such, lane marking is essential to AVs functioning properly and safely. More frequent lane marking would be costly, but the benefits outweigh the cost. One study found that "[o]n average, each $1 currently spent on pavement striping yields $60 in benefits," in terms of costs saved by lack of accidents, which can not only cause harm to the driver and automobiles, but also the road infrastructure.[88] While the study itself is somewhat dated, the values show the proportion of benefits to cost the city can still expect to see by implementing more frequent and brighter lane marking.

While the roads in the downtown area of Pittsburgh are usually well marked, some of the more suburban communities often do not have edgelines, or in some cases, even centerlines on the road. In order for AVs to be a viable option towards aiding underserved suburbanized communities, clear and complete lane marking needs to be implemented more frequently. These measures should first be adopted in the areas where the city plans to use autonomous shuttles and where autonomous ride-sharing is most likely to evolve, and then expanded to the city as a whole once AVs are prevalent on Pittsburgh streets.

[88] Ted R. Miller, "Benefit-Cost Analysis of Lane Marking," Federal Highway Administration, March 1993, accessed 10 December 2017, https://www.fhwa.dot.gov/publications/publicroads/93summer/p93su4.cfm.

Vehicle to Infrastructure Technology

AVs have a higher chance of success at navigating intersections and improving traffic flow in a city with connected infrastructure that can communicate traffic patterns, traffic signals, and signals from other vehicles to increase traffic flow and sync acceleration/deceleration. This ability to communicate with traffic lights is V2I technology. V2I is already present in Audi's Q7 and A4 models and Cadillac's CTS Sedan as of 2017. Audi vehicles are equipped with a built-in LTE data modem that can communicate with traffic signal systems to alert the vehicle of a countdown for when the light changes. GM has started putting Dedicated Short-Range Communications (DSRC) in all of its new Cadillacs. DSRC is a short to medium-range wireless communication that can be used in both V2V and V2I technologies to avoid collisions and coordinate traffic stops.[89]

In the future, AVs will be able to communicate with traffic signals with these same capabilities installed to slow down, stop, and start in conjunction with the changing signal rather than relying on the vehicles' less reliable visual sensors. This is important not only because it can help reduce the chance of gridlock, but also since an AV's cameras can get blinded if the sun is directly behind a traffic light. In that case, as with human drivers, seeing a traffic light is nearly impossible and added implementation of traffic light sensors in conjunction with V2I technology in both non-autonomous and autonomous vehicles can markedly improve safety and efficiency.

Regulations that require the installation of V2V communication technology in light-duty vehicles were proposed by the Department of Transportation in 2016, and it is likely that within

[89] Department of Transportation, "DSRC: The Future of Safe Driving," Office of the Assistant Secretary for Research and Technology, *United States Department of Transportation,* accessed 10 December 2017, https://www.its.dot.gov/factsheets/dsrc_factsheet.htm.

the next 5 years, this technology will become a staple in privately owned vehicles.[90] With these capabilities in vehicles, they will also be able to communicate to Intelligent Transportation Systems radio service and cellular service implemented in Pittsburgh's transportation infrastructure in traffic lights. BMW, Mercedes, Audi, and GM have all begun installing V2V and V2I technology into some of their models, anticipating the inevitable need and use of this technology to improve traffic flow and safety.

It is now time for cities to do the same and begin putting in technology that these companies can work with to test and evaluate how well their new systems are operating. In the short-term, Smart City technologies will be useful even while the automobile market mostly consists of low-level or no automation vehicles, but these technologies will become increasingly crucial in maintaining traffic safety as automation progresses. If low-level and no automation vehicles have V2V and V2I capabilities, the unpredictability of mixed-level automation will no longer be a concern. All vehicles will communicate with each other and Smart City infrastructure to reduce risk and human error.

The first step is implementing communication capabilities into the infrastructure. Traffic lights need to be able to communicate with not only each other, but with vehicles to optimize traffic flow, which will in turn help AVs be even safer than when just relying on their sensors. More reliable LTE communications have even stronger signals to communicate with cars such as the Audi Q7 and A4, which are already equipped with the capabilities to relay LTE. The city should use money from the Smart City Challenge and search for other state and federal grants to

[90] National Highway Traffic Safety Administration, "U.S. DOT Advances Deployment of Connected Vehicle Technology to Prevent Hundreds of Thousands of Crashes," accessed 27 September 2017, https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands.

replace traffic lights throughout the city with LTE communication capabilities, starting with the areas that receive the most traffic.

Smart Corridors for Research

Pittsburgh and the state of Pennsylvania have an interest in attracting innovators and developers of AVs and related smart city technology by developing spaces that incentivize research testing. Projects such as the Smart Mobility Corridor in Ohio and the advanced mobility testing centers that states such as Nevada and Michigan have developed are highly effective at attracting investments and interest from technology companies. The Smart Mobility Corridor in Ohio was created through an initiative started by Governor John Kasich in partnership with Honda, the Transportation Research Center at East Liberty, and the Ohio State University Center for Automotive Research. The corridor is a 35-mile stretch of highway outfitted with highway sensors and fiber optic networks that allow government and private-sector research vehicles equipped with data-collecting hardware to test their V2I technology in a variety of traffic flow and weather conditions. For instance, Las Vegas, Nevada has taken advantage of the Nevada Center for Advanced Mobility Center's work on developing innovative V2I technology to research and implement safer and smoother transportation.

The recently constructed Highway 43 in the South Hills seems like an ideal stretch of road to implement smart corridor technologies especially since the road has multiple passing lanes, allows for high speeds, and has extremely light traffic. The road would also allow interested companies in testing AVs on slightly hilly terrain, which could be appealing in contrast to the flat landscape of Ohio's corridor. Although implementing a smart corridor would be expensive and mostly under the state's purview, Pittsburgh needs to take a lead on such a

project in order to incentivize more rigorous AV testing around Pittsburgh and get more AV companies to test in the Pittsburgh region. The 2017 Pennsylvania state budget has $11 million specifically earmarked for smart corridor development, and the federal government implemented a price-matching scheme of up to 40% of costs for Ohio, indicating that a smart corridor could be created with very little risk to Pittsburgh itself.[91] In addition, for reference, Ohio's smart corridor has helped raise $217 million in investments from various companies and grants in the Columbus area, which demonstrates the tremendous upside that Pittsburgh could gain were it to help implement a smart corridor in the nearby vicinity.[92] As 2017 comes to a close, with little competition for the money earmarked for smart corridor development, Pittsburgh needs to hurry and forward its proposal for a smart corridor as soon as possible.

Conclusion

Considering the historical pattern of troubles that certain communities face with the onset of new transportation technologies, these proposals are the essential next steps for the City of Pittsburgh and Allegheny County to guarantee equitable access to transportation for underserved communities. Furthermore, these proposals allow the city and county to capitalize on the potential for economic growth and transportation efficiency brought by AVs. However, the proposals listed in this report are not exhaustive and further steps are required to expand on the communities that could benefit from AVs. While specific proposals have been made in regard to the implementation of AVs in Duquesne, the same considerations must be made for other

[91] Tom Wolf, "2017-2018 Governor's Executive Budget," accessed 10 December 2017, http://www.budget.pa.gov/PublicationsAndReports/CommonwealthBudget/Documents/2017-18%20Proposed%20Budget/2017-18%20Budget%20Document%20-%20Web.pdf.
[92] "Ohio's 33 Smart Corridor," accessed 10 December 2017, https://www.33smartcorridor.com/.

underserved communities within the city and its surrounding suburbs. The city and county should carry out similar investigations to determine the best way to implement AVs in other communities to ensure equitable access to transportation. The City of Pittsburgh and Allegheny County must investigate how these proposals can benefit underserved communities while preparing Pittsburgh for the future of transportation.

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