

Automated Vehicles for a Sustainable City

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Dow Interdisciplinary Sustainability Fellowship, University of Michigan, Ann Arbor
White Paper, December 2014

Acknowledgements

The authors would like to extend thanks to the Dow Sustainability Fellowship at the University of Michigan, and especially to Greg Bond, John DeCicco, and Anne Wallin for their guidance throughout the project. We are grateful to the many engineers, transportation planners, city officials, professors, and graduate students who helped us better understand the past and present of urban transportation, and shared with us their visions for future mobility.

We are especially grateful to the following people for their time and knowledge: Dave Askins; Lawrence Burns; Eli Cooper; Stephen Dolan; James Fishelson; Jonathan Levine; John Maddox; Joseph Morehouse; Louis Merlin; James Sayer, Huei Peng, Paul Portney; Don Scavia; Brandon Schoettle; John Viera; and Chris White.

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I. Executive Summary

The imminent possibility of vehicles that can communicate and operate without human intervention has struck many consumers as simply another incremental improvement in the long list of features now available on most new cars. Yet for reasons that will become clear in this white paper, vehicle automation and connection represents not just an incremental improvement to automobility, but a gradual mode shift away from our current transportation paradigm.

This mode shift comes with both peril and promise. In this white paper, we outline how the development of automation and connection as a personal vehicle technology presents the danger of a significant consumption rebound and increase in transportation carbon emissions. If drivers are freed up to perform other activities while "driving", they may choose to increase their travel by as much as 150%, accelerating the problem of carbon pollution.

Yet a competing vision for shared automated mobility holds significant promise as a means to reduce carbon emissions through electrification and vehicle right-sizing. The cost savings and high capacity utilization unlocked by automation and connection could make micro-rentals of vehicles radically affordable, offering vast social benefits at a reduced cost to both the environment and to consumers.

To advance this latter vision and achieve a proof of concept for a shared system of automated mobility, the University of Michigan's Mobility Transformation Center (MTC) will collaborate with government and industry partners to deploy a test fleet of up to 2,000 automated and connected vehicles in Ann Arbor. To assess the feasibility of this vision and guide its development, this white paper takes stock of the enablers, barriers, and legal issues involved with automated deployment in Ann Arbor specifically.

The enablers we identify are:

- The size of Ann Arbor: both large enough and small enough to serve as a viable testing ground.
- The population of Ann Arbor, which uses public transit avidly and includes a substantial representation of groups likely to be well disposed to vehicle automation.
- The technical sophistication of both the University and the city planners in Ann Arbor city government and at Ann Arbor Area Transportation Authority (AAATA).
- The Connected Vehicles, a test of vehicle-to-infrastructure communications technology that can serve as a key building block in the creation of a shared, automated vehicle fleet.

Alongside these encouraging findings, however, our white paper outlines several key barriers to the achievement of the vision of the mobility transformation center:

- A highly restrictive Michigan regulatory environment that limits vehicle automation to testing with a live driver at all times.
- Unresolved questions regarding liability and insurance
- A widespread lack of public understanding and acceptance
- The conservative nature of Ann Arbor's local transit planning processes, which is aimed not at innovation but at maximizing the probability of meeting transit demand and attracting federal funding.

Based upon a consideration of these factors, our analysis highlights a key opportunity for the Mobility Transformation Center in the supplementation of Ann Arbor's bus system, which currently services several routes at an extremely low level of utilization for lack of a better option. Automated and connected vehicles address that need effectively and precisely. If level four (fully driverless) automation can be achieved and legally sanctioned by 2021, the supplementation of the current bus system in Ann Arbor will serve as an excellent incremental proof of concept for a shared, automated, and connected vision of mobility.

To further pursue this option, MTC should consider the following research and outreach strategies to capitalize on opportunities and overcome barriers for deployment:

Legal, regulatory, and liability framework:

- Further research on the local, state, and federal regulation of roadways and how regulation of these roadways may affect AV use should be completed.
- Further research should be completed on the difference between regulating automated vehicles as individual entities and regulating ACV systems, in which automated vehicles are not only connected to other vehicles, but also to a larger cyber-infrastructure.
- Researchers should pay close attention to California's pending regulations governing not only the testing, but also the public use of automated vehicles.
- Researchers should also anticipate ways to limit upfitter liability for any accidents automated vehicles cause, and may also consider how Michigan statute could be amended to allocate liability more clearly.
- Further research should also address the privacy concerns automated technology raises and find a way to prevent the hacking (and potential hijacking) of automated vehicles.

Public trust and consumer acceptance:

- MTC should perform a representative survey within the city of Ann Arbor on consumer perceptions and trust of self-driving vehicles.
- Researchers should perform interviews with representatives from active community organizations, like the Ann Arbor Parent-Teachers Organization, to gauge their optimism and concerns regarding ACV technology. These private meetings should be followed with public meetings to openly air concerns related to the technology and educate community members on the benefits and proven capabilities of the technology, as well as possible scenarios for deployment.

City government, AAATA, and other key stakeholder concerns:

- MTC should engage with key local stakeholders including:
 - City Administrators
 - City Council
 - The Board of the AAATA (focus on AAATA as potential owner/operators of ACV fleet)
 - The Downtown Development Authority (focus on ACV deployment as a solution to parking challenges)
 - University of Michigan Parking and Transportation Services
 - Michigan Department of Transportation
 - Michigan State Lawmakers
- In its survey of Ann Arbor residents, MTC should ask specifically how residents would feel about reducing parking availability in Ann Arbor if improved ACV transit options were available.
- MTC should work with potential allies to identify the steps necessary to secure investment in V2I infrastructure and develop a plan to maintain the integrity of that infrastructure.
- MTC should identify all potential federal funding sources for improved transportation projects, including those available through FTA and NHTSA, and generate scenarios based on different levels of funding availability.
- MTC should then collaborate with allies in city government and City Council to present plans for V2I infrastructure installation and maintenance to potential opponents.

- Pending the results of Ann Arbor public opinion surveys and outreach to active community organizations, MTC should encourage allies of the deployment to contact City Council members to express their support for the test fleet.

Supplementation of AAATA bus system with ACVs:

- MTC should perform a detailed analysis of hour-by-hour ridership on select AAATA routes operating within the Ann Arbor city limits to identify opportunities for replacement of full-size busses with smaller, on-demand ACVs.
- MTC should reach out to AAATA to determine the feasibility and costs of system overhauls to accommodate a mixed ACV/bus fleet, as well as to better understand how this fleet redesign would change the revenue and cost structure of AAATA.

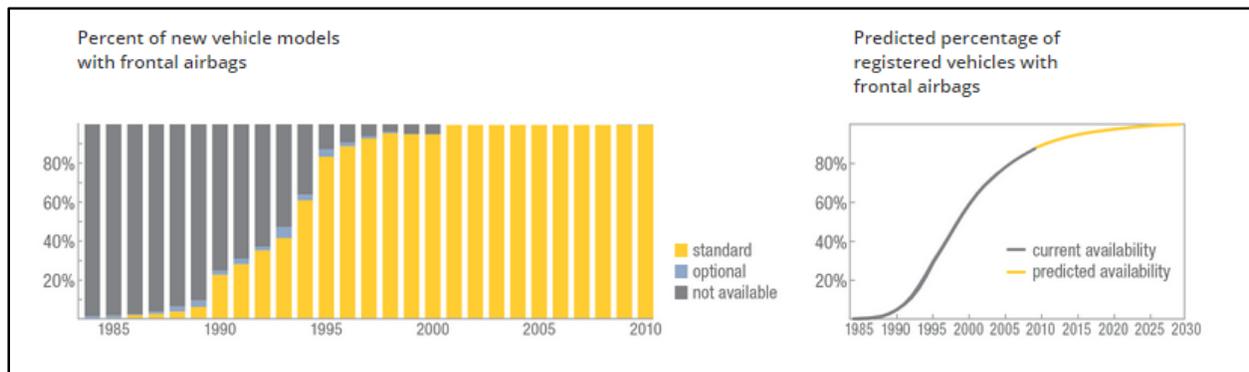
II. The Perils of Automation

Private adoption of automated vehicles is the most likely path forward

The private ownership model of automated vehicle mobility appears to be by far the most likely path by which automation will diffuse into the American transportation mix. The history of vehicle innovations have repeatedly followed the path of luxury introduction followed by mass adoption, and recent incremental steps toward automated vehicle functions -- such as adaptive cruise control (which automatically adjusts vehicle speed to maintain a safe distance from vehicles ahead) and automated parallel parking -- have been introduced as luxury features.

Even the safety features that are now commonplace in the majority of cars followed this path. The uptake of automatic frontal airbags was led by luxury automakers and has taken decades. The National Highway Traffic Safety Administration (NHTSA) sought to make automatic airbags mandatory in 1976 for all new vehicles after years of struggling to encourage American drivers and passengers to wear seatbelts.¹ Auto manufacturers protested adamantly, and received a compromise to make 250,000 vehicles with airbags each year that would be sold to consumers and monitored by NHTSA to gather information about their effectiveness. A year later, the transportation secretary ordered that airbags be installed in all luxury vehicles by 1982. Jaguar and Mercedes-Benz, two luxury auto makers, were the first to voluntarily include frontal airbags in new cars.

Figure 1: Timeline of introduction of automobile safety features



Source: Chappell, Lindsay. Automotive News. "GM's airbag concept inflated slowly." (2004). <http://www.autonews.com/article/20040802/SUB/408020802/gms-airbag-concept-inflated-slowly>

Recent polling conducted by the University of Michigan Transportation Institute (UMTRI)'s human factors team suggests that this path of diffusion remains the likeliest for automated vehicles. Schoettle & Sivak (2014) found that while a significant percentage of

¹ Waters, Wendy. New Directions Road Safety Institute. "A Half Century of Attempts to Re-Solve Vehicle Occupant Safety: Understanding Seatbelt and Airbag Technology." <<http://www-nrd.nhtsa.dot.gov/pdf/ESV/esv16/98S6W24.PDF>> 1996.

Americans were interested in automated technology, only a small minority were willing to pay for them. See summary chart below:

Figure 2: Willingness to pay for Level 4 automation technology

Measure	U.S.	U.K.	Australia	Total
10 th percentile	\$0	\$0	\$0	\$0
25 th percentile	\$0	\$0	\$0	\$0
50 th percentile (median)	\$0	\$0	\$0	\$0
75 th percentile	\$2,000	\$1,710	\$2,350	\$1,880
90 th percentile	\$5,800	\$5,130	\$9,400	\$8,550
Percent responding \$0	54.5%	59.8%	55.2%	56.6%

Source: Schoettle, Brandon, and Michael Sivak. "A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia." (2014).

A willingness-to-pay survey about a technology that customers have never experienced is obviously a rather imprecise instrument. However, if we take these results to be representative, we can assume that 10% of the US population is willing to pay \$5,000 for a vehicle equipped with full (Level 4) automation. This suggests a highly attractive niche market, analogous to the initial niche market for other luxury vehicle features. Assuming (for the moment) a resolution of the complex legal issues, this luxury consumer toehold could (1) generate sufficient data and familiarity to convince a wider range of consumers to embrace automated vehicle technology and (2) provide sufficient demand for manufacturers to develop economies of scale and reduce costs down to the point where automation could be offered to more price-conscious consumers. Were this developmental process to obtain, it would represent a progression analogous to the introduction of cruise control, automatic transmission, and airbags.

Widespread private ownership of automated vehicles may be a net loss for the environment

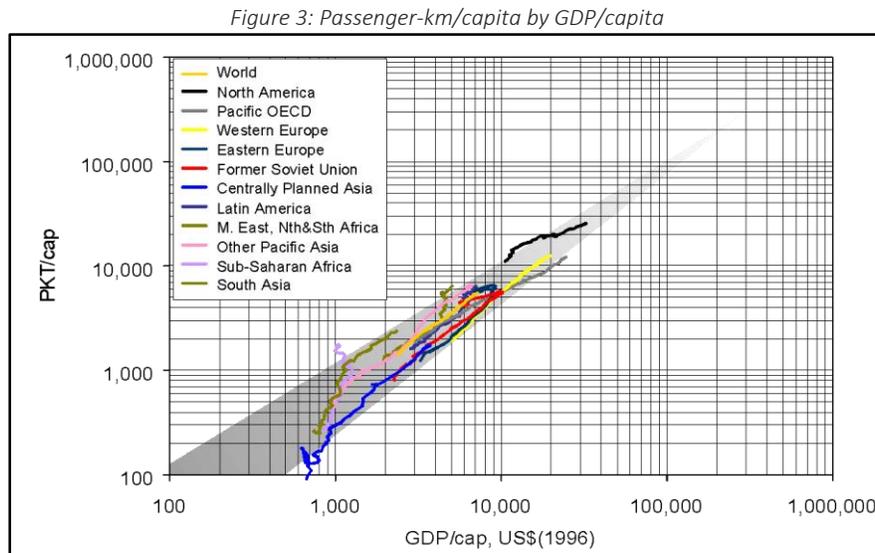
As has been pointed out by many observers², there would be potentially many efficiency gains offered by automation. Even if we were to accept the most optimistic scenarios regarding the efficiency of automated vehicles, however, it must be remembered that there are two

² "Self-Driving Cars Could Cut Greenhouse Gas Pollution." *Scientific American Global RSS*. 15 Sept. 2014.

"Energy Implications of Autonomous Vehicles: Imagining the Possibilities." *Energy Implications of Autonomous Vehicles: Imagining the Possibilities*. 9 Sept. 2014.

components to any pollution identity: the efficiency of consumption and the total amount consumed.

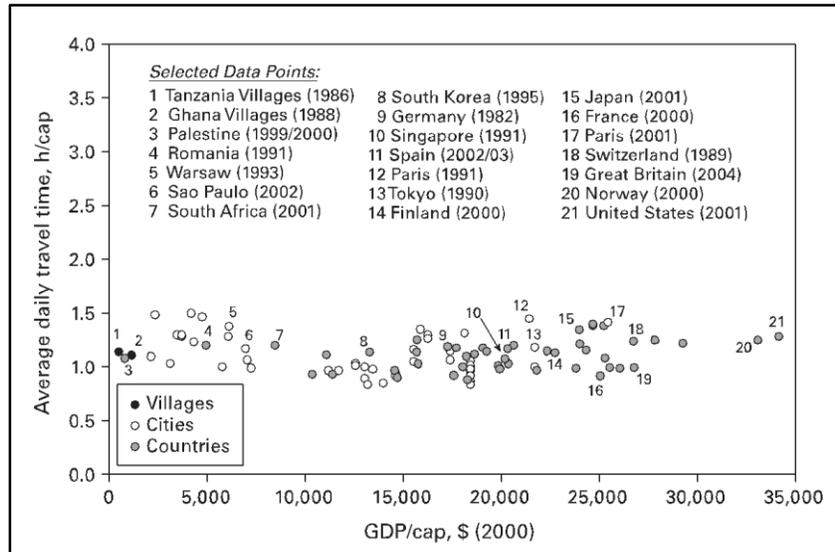
The development of world energy resources, transportation technology, and overall growth in wealth has led to a dramatic increase in the distances traveled by consumers of mobility. This is demonstrated in the Figure 3 below, which shows passenger-km per capita over per capita GDP for 11 world regions and the world between 1950 and 2000:



Source: Schäfer, Andreas. "Long-term trends in global passenger mobility." *Frontiers of Engineering: Reports on Leading-Edge Engineering from the 2006 Symposium*. National Academies Press, 2007.

Remarkably, however, this growth in distances traveled by the average consumer has not been matched with growth in the amount of time spent in transit. In a cross-cultural study of average daily travel time, Andreas Schäfer found that travel time budgeting is remarkably stable across all categories of wealth and income: "On average, residents in African villages, the Palestinian Authorities, or suburbs of Lima spend about 1.2 hours per day traveling, as do those living in the automobile dependent societies of Japan, Western Europe, or the United States." See Figure 4 below:

Figure 4: Daily travel time by GDP/capita



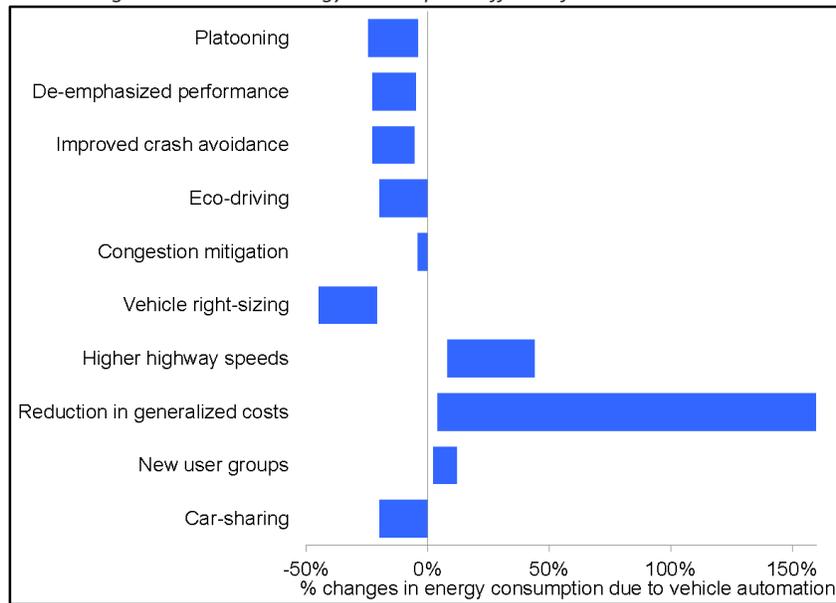
Source: updated dataset of Schäfer, A., D.G. Victor, 2000. The Future Mobility of the World Population, Transportation Research A, 34(3): 171–205.

From an energy and carbon perspective, this remarkable constancy in travel time budgeting has been a saving grace. Despite enhancements to the comfort of travel provided by vehicle amenities, and despite the wide range of newly accessible destinations afforded by advanced transportation infrastructures, travel time has not risen with technology.

It is in this sense, then, that vehicle automation as a personal transportation technology could increase total transportation carbon emissions. Personal automated vehicles capture all of the benefits of personal automobility (flexibility in departure time and route, personalized space, etc) while vastly reducing the time cost associated with driving. If travel is not experienced as being time-costly, travel time budgets may expand dramatically. Another way of putting this is the rhetorical question: what length of commute might you accept if you could work or sleep throughout the drive?

Researchers are currently working to contextualize this downside potential alongside the benefits that automation offers in terms of efficiency. In a comprehensive inventory of the potential impacts of automation in the United States, Mackenzie, Wadud, and Leiby calculate the potential energy consumption effects of automation in Figure 5 below:

Figure 5: Potential energy consumption effects of vehicle automation



Source: MacKenzie, Don, Zia Wadud, and Paul Leiby. "A First-order Estimate of Energy Impacts of Automated Vehicles in the United States." http://cta.ornl.gov/TRBenergy/trb_documents/2014_presentations/697_MacKenzie_.pdf

The “reduction in generalized costs” effect is both the most concerning and the most uncertain. It represents a (1) reduction in insurance costs associated with improved safety and, most importantly (2) the reduction in “time cost” associated with travel. Essentially, MacKenzie et al model time cost as part of the overall cost of mobility and posit a consumption rebound associated with the reduction of that cost.³

In doing so, they project an increase in vehicle miles traveled between 30-150%. Applied to today’s transportation energy consumption patterns in the US, this VMT increase would translate into an increase of between 4 and 20 million barrels a day of oil.⁴ Such an increase would represent between 2 and 9 metric megatons of additional carbon pollution (TgCO₂-eq).

These considerations point to the significant peril represented by the private ownership model of automated vehicle deployment: the potential to engender travel and land use patterns far worse than those currently extant. To maximize the environmental potential of vehicle automation technology, then, we must advance a different model of automated mobility.

³ This procedure assumes that time cost reductions are analogous in their effects to gasoline price reductions, which have a long track record of stimulating increased travel consumption. They assume an elasticity of travel demand with respect to generalized cost: of -1.0 to -2.0, which appears to be a rather aggressive assumption based upon the findings of Lee (2000) For more information see:

Litman, Todd. "Transportation elasticities." *How Prices and Other Factors Affect Travel Behavior Victoria Transport Policy Institute* (2007).

⁴ Conti, J. J., et al. "Annual Energy Outlook 2014 with projections to 2040." *US Energy Information Administration* (2014).

II. The Promise of Automation

A different vision of automated mobility

There remains, however, a fundamentally different vision of automated vehicle technology implementation that would have vastly different environmental implications: the model of shared, connected, automated vehicles owned not by travelers but by a government, non-profit, or private enterprise. The first building block for such a system—vehicle communications technologies—is already being piloted in Ann Arbor.⁵

A connected fleet of automated vehicles could be summoned by travelers on demand, and operate as shared mobility solutions for entire communities. This fleet model of AV deployment has received significant research attention. In a case study of multiple cities including Ann Arbor—home to 120,000 vehicles and 528,000 internal trips per day—Burns & Scarborough calculate that a fleet of 18,000 automated vehicles would be needed in order to keep wait times down to less than 1 minute per traveler.

Such a system would cost around \$0.40 per mile to operate, dramatically lower than the average \$2.35 per mile charged by Uber.⁶ These savings come from labor cost reductions, but also from the reduced vehicle cost that comes from fitting each vehicle to each trip. This “right-sizing”, combined with the electrification that such a model would facilitate, holds vast promise from an environmental perspective.

Electrification and right-sizing: the key environmental benefits of automated fleets

Most personal vehicles are overpowered and oversized relative to the vast majority of trips they service. The average trip is taken by individuals driving alone, and yet the average vehicle is equipped to transport at least four people. The average trip distance is 12.09 miles, and yet the typical vehicle range is over 300 miles.⁷ The average speed of commuters is 29 mph, and yet the average vehicle is engineered to reach speeds of 70+ mph.⁸

This excessive capability leads to far worse environmental performance than is possible. Yet such purchase decisions are rational from a personal ownership standpoint. The flexibility and freedom conferred by automobiles is highly valued by consumers, and until now has only been fully attainable through private vehicle ownership.

⁵ For more information see: http://www.its.dot.gov/safety_pilot/

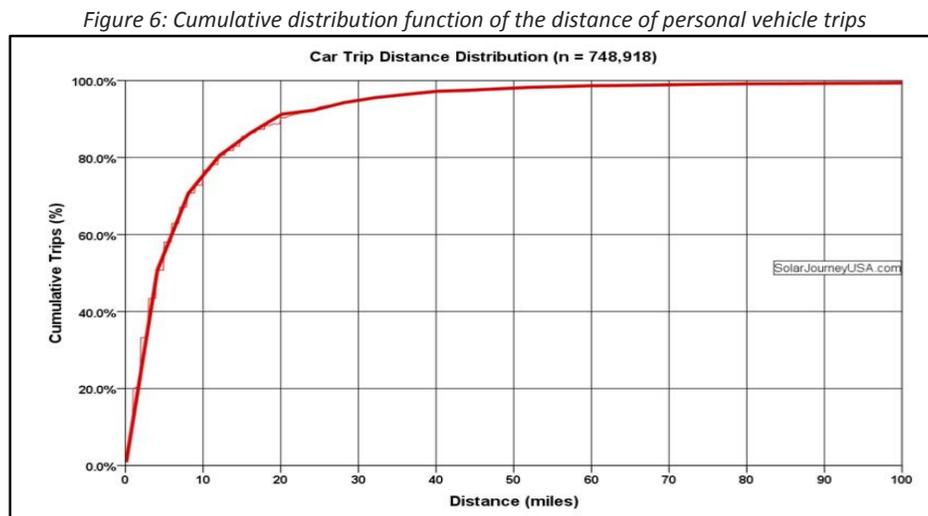
⁶ Silverstein, Sara. "These Animated Charts Tell You Everything About Uber Prices In 21 Cities." *Business Insider*. Business Insider, Inc, 16 Oct. 2014.

⁷ Based on the production weighted average tank size of 19.3 gallons and an average fuel economy of 17.92 mpg found in the Volpe Model Market Data file for Model Year 2011.

⁸ Santos, Adella, et al. *Summary of travel trends: 2009 national household travel survey*. No. FHWA-PL-II-022. 2011.

Shared, connected, and automated vehicle fleets represent the first opportunity to deliver the same degree of flexibility and freedom, at lower cost both to travelers and to the environment. A centrally managed fleet of automated and connected vehicles could be tailored to the specific range and performance requirements of the full distribution of trips required.

By shifting vehicle choice from a long-term purchase to a short term rental or service subscription, many of the barriers to vehicle right-sizing would evaporate. Limited-range electric vehicles, which currently struggle to attract consumers desirous of the freedom offered by a gas tank, could be effectively integrated in a system where travelers can summon longer-range, larger-capacity liquid fuel powered vehicles when needed. Such occasions would be rather rare. Below is presented a cumulative distribution function of the distance of personal vehicle trips:



Source: Van Haaren, Rob. "Assessment of electric cars' range requirements and usage patterns based on driving behavior recorded in the National Household Travel Survey of 2009." *Earth and Environmental Engineering Department, Columbia University, Fu Foundation School of Engineering and Applied Science, New York* (2011).

As shown above, 95% of all trips taken are for less than 30 miles. However, based on the sustained range anxiety about electric vehicles, it would appear that most consumers value the option of long range trips highly. Assuming (conservatively) that electric vehicles would have a range of <50 miles, this indicates that electrification is far more theoretically viable under a shared, automated model of mobility than under a personal ownership model.⁹

A similar dynamic would allow single occupancy vehicles to thrive in a shared fleet mobility system. Over 75% of daily commutes are single occupancy, indicating that small 1- to 2-

⁹ It should be acknowledged that any centrally managed fleet would have to contend with the tension between the charging time required for electric vehicles and the need to achieve high capacity utilization in order to keep prices low. A fleet of short-range electric vehicles would have to be larger than a fleet of liquid fuel-powered vehicles in order to serve equivalent populations, unless battery swapping technology were employed. Indeed, battery swapping itself is another example of an innovation that is predictably viable in a centrally managed fleet than in a paradigm of personal ownership.

person vehicles could constitute the vast majority of a shared fleet system.¹⁰ MacKenzie et al calculate that vehicle right-sizing could result in 25-50% reductions in road vehicle energy intensity.¹¹

Two competing visions

Thus far, this white paper has contrasted the benefits offered by shared automated vehicles with the environmental risks of automation as a personal luxury technology. In all likelihood, this technology will eventually be deployed in both such manners. However, insofar as this process of technology adoption is path dependent, it is incumbent on environmental advocates to vigorously advance automated fleet mobility as a responsible community solution to the mobility needs of citizens.

This then raises the question: how can advocates of sustainable mobility advance this vision? If Burns & Scarborough are correct, the economics of shared Automated/Connected Vehicle (ACV) vehicle ownership are sufficiently favorable to suggest that perhaps profit-seeking entities can be relied upon to deliver such a system unaided by government, nonprofit, and citizen groups.

One must recall, however, that this model of automated vehicle deployment is in competition with the far more established, and far less risky, "luxury introduction path" that ends in an automated vehicle in every garage. To level that playing field, a proof of concept is required in order to spur investment in the community-level automated mobility.

Governments in Europe have already responded to that call. The European Union's CityMobil2 initiative is currently launching deployments of low-speed automated cars and buses in seven cities.¹² Funded by the EU's Seventh Framework Programme for research and technological development (FP7)¹³, the multi-stakeholder project has selected three cities for six-month large scale deployments of automated transport systems, and four additional towns for two month small scale deployments. By launching automated systems in diverse urban environments across multiple countries, FP7 will begin building public awareness about automated systems, while improving auto-makers' and policy makers' understanding of the interactions between



¹⁰ McKenzie, Brian, and Melanie Rapino. *Commuting in the United States: 2009*. US Department of Commerce, Economics and Statistics Administration, US Census Bureau, 2011.

¹¹ It should be noted that safety, rather than capacity, is another concern leading some consumers to opt for large vehicles. Since safety is perhaps the most significant motivating force behind automation research, it may be possible for even a small automated vehicle to outperform a large, human-operated vehicle from a safety perspective.

¹² CityMobil2. Retrieved from: <http://www.citymobil2.eu/en/>

¹³ Seventh Framework Programme for Research and Technological Development. *European Union*. Retrieved from: http://ec.europa.eu/research/fp7/index_en.cfm

automated vehicles and other road users. Finally, in addition to the pilot activities, systematic research will be undertaken into the technical, financial, cultural, and behavioral aspects and effects on land use policies and how new systems can fit into existing infrastructure in different cities.

Given the significant difference between American and European mobility challenges, however, a domestic proof of concept will be needed in order to stimulate the dominance of fleet mobility in the United States. CityMobil2 represents an important forward-thinking initiative to tackling the barriers to the deployment of automated transport systems, and will be referenced throughout this paper as a strategic model that exemplifies the potential impact that cohesive federal support could have on similar local pilot deployments in the US.

The next section of this paper considers the benefits of, and barriers to, such a demonstration project being undertaken in Ann Arbor, Michigan.

III. 2020 Deployment in Ann Arbor

The University of Michigan's Mobility Transformation Center (MTC) leads interdisciplinary research to accelerate the development and deployment of ACVs regionally, nationally and globally. Among the center's goals is to put a pilot fleet of shared ACVs on the road in Ann Arbor by 2020. In addition to engineering R&D, the effort must tackle many social and institutional issues in order realize its ambitious goals. The following sections outline the factors that present potential enablers and barriers to the MTC successfully introducing ACVs in a way that establishes their economic value and sustainability benefits to the wider Ann Arbor community.

A. Enablers

City size

One of the primary enablers of launching an ACV demonstration fleet in Ann Arbor is the city's size.¹⁴ With a population of approximately 117,000 people at a relatively modest land area of 27.83 square miles,¹⁵ Ann Arbor is not too large to prevent timely investment in Vehicle-to-Infrastructure (V2I) communications equipment throughout the city that would be necessary for such a fleet rollout. However, Ann Arbor is also large enough to present a diverse testing ground for ACVs and could provide meaningful data and analysis showing how ACVs operate in wide range of environments, included a crowded and vehicle-heavy city center, a pedestrian- and cyclist-heavy university, and less dense and thoroughly suburban surrounding neighborhoods.

¹⁴ Schoettle, Brandon. (2014, Nov. 18). University of Michigan Transportation Research Institute. Personal interview.

¹⁵ U.S. Census Bureau (2013). Ann Arbor (city), Michigan. American Community Survey 2013 Estimates. Accessed on 11/29/2014. Retrieved from: <http://quickfacts.census.gov>

In terms of size, Ann Arbor can be compared to La Rochelle, the medium-sized city (pop. 146,000) in western France that CityMobil2 selected as the pilot launch site to test the deployment of automated, electric buses in busy city centers. As is the case in La Rochelle, if ACVs can demonstrably perform safely and provide a meaningful transportation service in Ann Arbor, they can be shown to provide transportation and sustainability benefits for many other medium-sized communities in the United States, and perhaps even provide the boost in public confidence needed to deploy similar pilots in larger cities.

Demographics

Another enabler is Ann Arbor's relatively young, highly educated populace, which is the demographic group that has expressed the highest rates of interest in ACV technology, as well as an increasing shift towards shared or public mobility systems. About 47.3% of Ann Arbor's population falls between the ages of 20 and 44, compared with 31.6% across Michigan. Furthermore, 70.8% of Ann Arbor residents have a bachelor's degree or higher, compared with 25.5% throughout the state.¹⁶ According to the think tank the Frontier Group, 16- to 34- year olds in American households with incomes over \$70,000 increased their public-transport use by 100% from 2001 to 2009¹⁷. The share of young households without cars also increased from 20% to 28% between 1998 and 2008, and a global survey of teen attitudes by TNS found that young people increasingly view cars as appliances, not aspirations. Given this context, it comes as no surprise that recent survey research on consumer acceptance of automated vehicle technology shows that younger and more highly educated consumers are more receptive to automated vehicle technology. Students were specifically identified as a group more interested in the technology, making Ann Arbor a potentially attractive market for the deployment of ACVs.¹⁸

Proportion of commuters

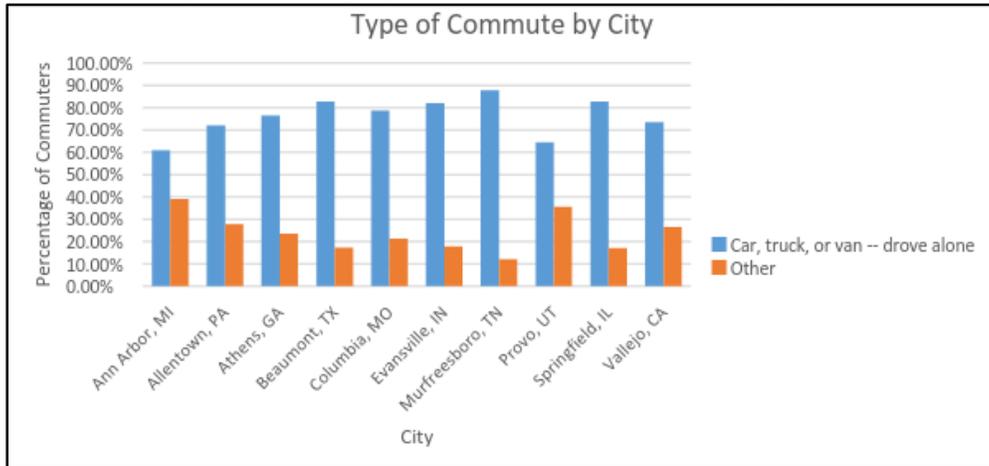
Ann Arbor is also promising given its relatively high proportion of commuters who are likely to use transportation means other than driving solo, which indicates that Ann Arbor has a relatively well-developed public transit system for its size and that there exists a sizeable number of commuters who may be in the market for using shared ACVs for their commute. As shown in Figure 7 below, when compared with 9 similarly sized US cities that are not immediate suburbs of larger cities, Ann Arbor has the lowest percentage of commuters who regularly drive alone (60.96%) among the 10 reference cities. Furthermore, Ann Arbor has the highest percentage of commuters who use public transportation for their commute (10.62%), as shown in Figure 8.

¹⁶ *Ibid.*

¹⁷ "Seeing the Back of the Car." *The Economist*. The Economist Newspaper, 22 Sept. 2012. Web. 22 Nov. 2014. <<http://www.economist.com/node/21563280>>.

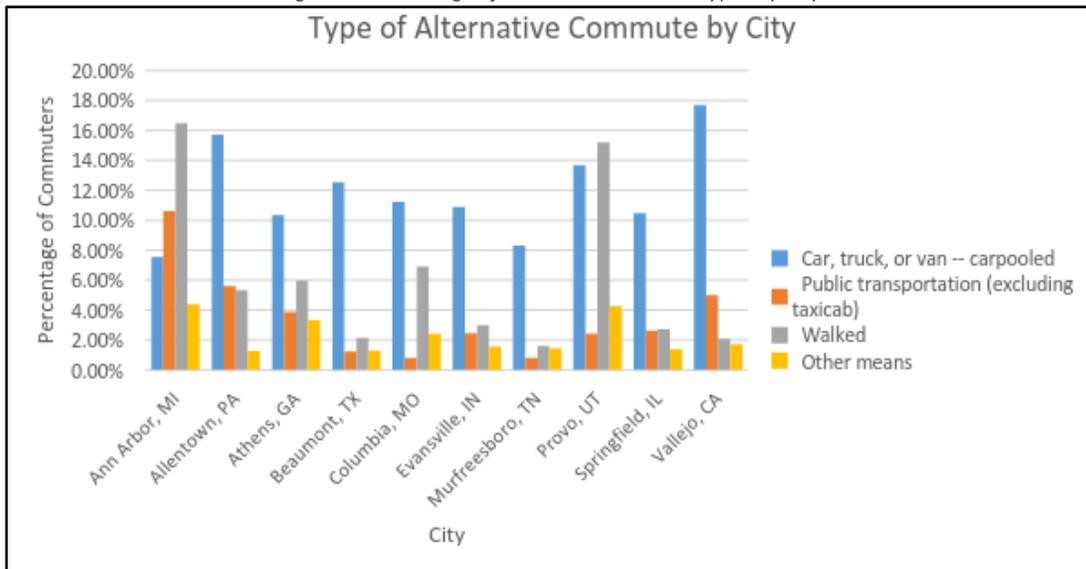
¹⁸ Schoettle, B., and Sivak, M. (2014, Oct.). Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia. *University of Michigan Transportation Research Institute*.

Figure 7: Percentage of Commuters Who Drove Alone to Work by City



Source: U.S. Census Bureau (2013). Ann Arbor (city), Michigan. American Community Survey 2013 Estimates. Accessed on 11/29/2014. Retrieved from: <http://quickfacts.census.gov>

Figure 8: Percentage of Alternate Commute Types by City



Source: U.S. Census Bureau (2013). Ann Arbor (city), Michigan. American Community Survey 2013 Estimates. Accessed on 11/29/2014. Retrieved from: <http://quickfacts.census.gov>

Demonstrated potential for local benefits

Ann Arbor has received the sustained attention of analysts attempting to model the implications of shared ACV system. In addition to the favorable modeling results constructed by Burns *et al*, Merlin (2014) is also building a transit model specific to Ann Arbor that can run different scenarios of shared automated vehicle and public transit deployment and consider the travel choice and cost-benefit implications of each scenario.¹⁹ These and other Ann Arbor specific case studies can provide valuable *ex ante* evidence of the potential benefits of

¹⁹ Merlin, L. (2014, Oct. 30). Shared automated vehicles and transit – 14.30 The automated car and the city. *University of Michigan – Taubman College of Architecture and Urban Planning*.

introducing an ACV demonstration fleet in Ann Arbor, particularly when working with the high technical capacity of planners at the Washtenaw Area Transportation Study (WATS) and Ann Arbor Area Transportation Authority.

Returning to the CityMobil2 example with La Rochelle, one can draw parallels between the French town's 10-year Urban Transport Plan and Ann Arbor's Transportation Master Plan. Both plans set as objectives multi-modal systems that shift away from private cars and towards transit-, pedestrian-, and bike-oriented development. La Rochelle has gone a step further and explicitly linked the societal benefits that automated transportation systems offer to the objectives of its Urban Transport Plan. Ann Arbor, similarly, would have much to gain from analyzing how connected and automated mobility systems can both contribute to its Transportation Master Plan and potentially change Ann Arbor's long-term transportation goals.

The Downtown Development Authority (DDA)

A potential enabler is Ann Arbor's relatively strong and active Downtown Development Authority, whose mission is "to undertake public improvements that have the greatest impact in strengthening the downtown area and attracting new private investments." While the DDA is perhaps best known for additions to downtown parking capacity, they also partnered with the City of Ann Arbor and AAATA to implement the *getDowntown Program*, which includes the go!pass free bus pass program for downtown employees. They have also been a contributing partner on the Ann Arbor Connector project²⁰ and have supported improved pedestrian mobility and bicycle infrastructure in the downtown area.²¹ DDA's relatively progressive transportation and development priorities may make them a valuable ally in encouraging other stakeholders to support an ACV demonstration fleet rollout.

Automated vehicle testing facility

Finally, a powerful enabler for an ACV demonstration in Ann Arbor is the automated vehicle testing facility that MTC is opening near North Campus.²² Beyond providing an excellent environment for testing ACV technology in a variety of settings, the test facility could be used to showcase ACV capabilities and enable the Ann Arbor community as well as other public and private entities to witness the technology in action. This could help overcome some of the consumer acceptance and public trust issues that currently plague the adoption of automated vehicle technology. For instance, MTC could open the test facility at certain times of the year and allow public rides through the course. As the technology becomes more advanced, MTC may be

²⁰ URS Corporation (2011, Feb. 21). Ann Arbor Connector Feasibility Study – Final Report. Accessed on 11/29/2014. Retrieved from: <http://www.aconnector.com/documents/feasibility-report.pdf>

²¹ Ann Arbor Downtown Development Authority (no date). Accessed on 11/29/2014. Retrieved from: <http://www.a2dda.org/>

²² Moore, N.C. (2014, June 2). Automated vehicle test facility to open this fall. *Michigan Engineering*. Accessed on 11/29/2014. Retrieved from: <http://www.engin.umich.edu/college/about/news/stories/2014/june/test-facility>

able to set up small outdoor tracks as part of large events like Art Fair or home football games and allow public rides in more real-world settings.

B. Barriers

However, there exist significant institutional barriers to the rollout of an ACV demonstration fleet in Ann Arbor, some of which are Ann Arbor-specific.

Legal, regulatory, and liability framework

Professor Bryant Walker Smith predicted that automated vehicles are “probably legal in the United States.”²³ Although this may be true, the legal regimes that govern automated vehicle use still contain many gaps that legislators will need to fill in the coming years.

a. State law

i. Michigan law

For now, state legislators play the most important role in determining the future of automated vehicle use. Although federal and international laws also govern some aspects of motor vehicle use, *see infra*, regulation of motor vehicle licensing and operation is generally left to the states as an exercise of their police power.²⁴ States are therefore free to regulate speed limits and vehicle safety features, for example, as long as these regulations satisfy minimum federal standards²⁵ and are not preempted by other federal statutes or regulations.²⁶

In December 2013, Michigan became the fourth state to pass legislation governing automated vehicle use.²⁷ The relevant Michigan statute currently prohibits automated vehicle use in automated mode on highways or streets²⁸ except for research and testing purposes.²⁹ Michigan’s statute defines automated vehicles broadly and includes all “motor vehicle[s] on which automated technology has been installed.”³⁰ This includes technology that “enables the

²³ Bryant Walker Smith, *Automated Vehicles Are Probably Legal in the United States*, 1 TEX. A&M L. REV. 411, 412 (2014).

²⁴ “The right to operate motor vehicles in public places is not a natural and unrestrained right, but a privilege subject to reasonable regulations in the interest of the public under the police power of the state. The police power has been exercised in many states [by, for example, regulating licensure.]” 108 A.L.R. 1162.

²⁵ Federal Motor Vehicle Safety Standards and Regulations, 49 C.F.R. part 571.

²⁶ *See, e.g., The Risks of Federal Preemption of State Autonomous Vehicle Regulations*, UNIV. OF WASH. SCHOOL OF LAW, available at <http://techpolicylab.org/wp-content/uploads/2014/12/UW-Law-Clinic-Research-Memo-to-the-ULC-The-Risks-of-Federal-Preemption-of-State-Regulations-of-Autonomous-Vehicles.pdf> (last accessed Jan. 6, 2015).

²⁷ P.A.1949, No. 300, § 665, added by P.A.2013, No. 231, Eff. March 27, 2014; *see also* Gabriel Weiner and Bryant Walker Smith, *Automated Driving: Legislative and Regulatory Action*, cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action (setting forth current state statutes and regulations addressing automated vehicles).

²⁸ MICH. COMP. LAWS ANN. § 257.663 (West 2014) (“Except as otherwise provided in [Mich. Comp. Laws Ann. § 257.665], a person shall not operate an automated motor vehicle upon a highway or street in automatic mode.”).

²⁹ *Id.* § 257.665 (governing research or testing of automated motor vehicles).

³⁰ MICH. COMP. LAWS ANN. § 257.2b(1). Although some analysts have suggested that low-speed vehicles (LSVs) might be an exception to any statute regulating automated vehicle use, *see* Bryant Walker Smith, *Automated Vehicles Are Probably Legal in*

motor vehicle to be operated without any control or monitoring by a human operator,” but does not include automated safety systems like automated blind-spot assistance.³¹

Google criticized the Michigan State Senate bill before it was enacted, noting that the legislation “would make Michigan the single state, of all the states that have enacted [autonomous vehicle] legislation, to limit [autonomous vehicles] to testing.”³² This, Google contended, would “put Michigan in an awkward position of having to play catch up to other states that have already embraced the future of where advancements in AV technology are ultimately headed.”³³

Nevertheless, a recent report on “autonomous” vehicle testing in Michigan published by the American Association of Motor Vehicle Administrators (AAMVA) stated that Michigan intends to focus on testing and not future public use, for the time being.³⁴ This, the AAMVA noted, will enable the state to address safety issues and unresolved insurance requirements. As state Senator Mike Kowall, who sponsored Michigan’s automated vehicle laws, explained, “You have to crawl before you can walkThat’s why we started with a testing piece of legislation We’re in the process right now of drafting legislation that’s going to be the enabling legislation for full functional autonomous vehicles . . . I hope sometime before the end [2014], I will have that introduced.”³⁵

Michigan’s automated vehicle testing legislation includes several important requirements. First, the law requires that organizations testing these vehicles submit to the Michigan Secretary of State proof that the car is insured.³⁶ At the moment, no special insurance is required to test automated vehicles. Instead, Michigan’s current no-fault insurance is sufficient.³⁷ Analysts predict that insurance plans designed specifically for automated vehicles will become a possibility as the use and acceptance of automated vehicle technology becomes

the United States, 1 TEX. A&M L. REV. 411, 517 (2014), it is unlikely that this loophole applies to automated vehicles in Michigan, because the automated vehicle provision applies to all “motor vehicles.” See MICH. COMP. LAWS ANN. § 257.25b (Michigan statute defining a LSV as a “self-propelled *motor vehicle*.”) (emphasis added).

³¹ MICH. COMP. LAWS ANN. § 257.252b.

³² Letter from Google to State Representative Frank Foster re: SB169, Legislation Dealing with Autonomous Vehicles (Dec. 4, 2013), available at <http://house.michigan.gov/sessiondocs/2013-2014/testimony/Committee222-12-4-2013.pdf>. See, e.g., NEV. REV. STAT. § 282A.100 (West 2014) (Nevada statute directing the Nevada Department of Motor Vehicles to adopt regulations governing the operation of autonomous vehicles in the state); see also CAL. VEH. CODE § 38750(e)(1) (West 2014) (California statute governing testing and use of autonomous vehicles).

³³ Google Letter, *supra* note 28.

³⁴ *Autonomous Vehicle Testing in Michigan*, AM. ASSOC. OF MOTOR VEHICLE ADMIN’RS, www.aamva.org/WorkArea/DownloadAsset.aspx?id=4907 (last accessed Nov. 12, 2014).

³⁵ Sean Slone, *Autonomous Vehicle Legislation*, THE COUNCIL OF STATE GOVERNMENTS KNOWLEDGE CENTER, <http://knowledgecenter.csg.org/kc/content/autonomous-vehicle-legislation> (Mar. 11, 2014, 3:19 PM).

³⁶ MICH. COMP. LAWS ANN. § 257.665(1).

³⁷ See *id.* (“[T]he manufacturer of automated technology performing that research or testing shall submit proof satisfactory to the secretary of state that the vehicle is insured under chapter 31 of the insurance code of 1956, 1956 PA 218, MCL 500.3101 to 500.3179.”).

more widespread,³⁸ but it is likely that these changes will occur at the business, rather than regulatory, level.³⁹

Second, organizations testing automated vehicles may only test vehicles under certain conditions. For example, only a designated employee or contractor may operate the car, an individual who is able to immediately control the car if necessary must be present in the vehicle, and the individual operating the car must be “licensed to operate a motor vehicle in the United States.”⁴⁰ Michigan law also requires that automated vehicles being driven for testing purposes display a special plate approved by the Michigan Secretary of State.⁴¹ The Secretary of State began issuing these “manufacturer” plates last April.⁴²

Michigan does not currently require a special drivers’ license to be able to operate an automated vehicle within the state. Whether states will require separate licenses for individuals to operate automated vehicles remains an open question. Some analysts theorize that once cars become truly autonomous, no drivers’ license will be required.⁴³ Until then, however, some sort of license will likely be required; particularly when the law requires an individual in the car to be able to take over control at a moment’s notice should the automated technology fail.⁴⁴

Michigan’s automated vehicle legislation also includes a special provision limiting civil liability for car manufacturers whose cars were subsequently fitted with self-driving features.⁴⁵ Once a car is fitted with automated technology, the party that developed or installed this technology, also known as an “upfitter,”⁴⁶ assumes liability for any accidents the technology causes.⁴⁷ For more information on the tort and product liability concerns automated vehicle technology raises and how these concerns interact with the upfitter liability provision, see “Other legal issues,” *infra*.

³⁸ Chunka Mui, *Will Auto Insurers Survive Their Collision with Driverless Cars?*, FORBES, (March 28, 2013, 9:16 AM), <http://www.forbes.com/sites/chunkamui/2013/03/28/will-auto-insurers-survive-their-collision-with-driverless-cars-part-6/2/>.

³⁹ *See id.* (discussing fact that use of automated vehicle technology will likely result in fewer, but more severe accidents, and that insurers may change their pricing plans as a result); Joseph B. White, *How Do You Insure a Driverless Car?*, WALL ST. J. (Aug. 7, 2014), available at <http://online.wsj.com/articles/driverless-cars-edge-onto-roadways-1407432414>.

⁴⁰ MICH. COMP. LAWS ANN. § 257.665(2).

⁴¹ *Id.* § 257.244.

⁴² *Michigan Issues First License Plates for Autonomous Vehicles*, AASHTO JOURNAL, <http://www.aashtojournal.org/Pages/040414MDOTplates.aspx> (Apr. 4, 2014).

⁴³ Doug Newcomb, *You Won’t Need a Driver’s License by 2040*, WIRED (Sept. 17, 2012, 1:42 PM) <http://www.wired.com/2012/09/ieee-autonomous-2040/>.

⁴⁴ MICH. COMP. LAWS ANN. § 257.665(2)(b).

⁴⁵ MICH. COMP. LAWS ANN. § 600.2949b(1)(a) (“The manufacturer of a vehicle is not liable and shall be dismissed from any action for alleged damages resulting from any of the following unless the defect from which the damages resulted was present in the vehicle when it was manufactured: (a) The conversion or attempted conversion of the vehicle into an automated motor vehicle by another person.”).

⁴⁶ MICH. COMP. LAWS ANN. § 257.2b(5) (defining an upfitter as a “person that modifies a motor vehicle after it was manufactured by installing automated technology in that motor vehicle to convert it to an automated vehicle” and specifying that “upfitter” includes a subcomponent system producer recognized by the secretary of state that develops or produces automated technology”).

⁴⁷ MICH. COMP. LAWS ANN. § 600.2949b(1)(a).

ii. Comparing Michigan law to other state laws

California, Florida, Nevada, and the District of Columbia have also enacted automated vehicle statutes,⁴⁸ and many other state legislatures are currently addressing proposed legislation.⁴⁹ At the moment, the enacted statutes govern testing only, although California is in the process of developing regulations that will govern automated vehicle use by the public.⁵⁰

The automated vehicle statutes and regulations currently on the books are similar in many respects. As in Michigan, the California, Florida, Nevada, and DC statutes and regulations define “automated” or “autonomous” vehicle technologies, set forth particular reporting requirements for organizations preparing to test automated vehicle technologies, and define the conditions required for testing to take place.

Although the statutes and regulations are similar in many respects, they differ in a few ways. First, for example, the California and Nevada and regulations do not require a human driver in the car.⁵¹ Florida requires a human driver to be present in the car, unless the car is being tested on a closed course.⁵² Like Michigan, however, DC requires a human driver to be present in the car and able to assume control at all times.⁵³

Second, DC and Florida, like Michigan, exempt the original car manufacturer from liability should an automated vehicle be involved in an accident.⁵⁴ California and Nevada, however, have not addressed any upfitter liability in their statutes and regulations.

Third, the state statutes and regulations set forth different training programs drivers must complete before being able to operate autonomous vehicles. California’s regulations require, for example, that manufacturers conducting testing of automated vehicles maintain a training program for automated vehicle drivers⁵⁵. The program must address, among other things, defensive driving techniques and include behind-the-wheel training.⁵⁶ Like Michigan, Florida’s statute does not include a provision on driver training.

Fourth, while Michigan, Nevada, and Florida require only that the automated vehicle operator have a valid driver’s license, California requires the operator to obtain a test vehicle operator permit.⁵⁷

⁴⁸ See CAL. VEH. CODE § 38750(d); FLA. STAT. ANN. § 316.86; NEV. REV. STAT. ANN. § 482A.100; D.C. CODE § 50-2352; see also NEV. ADMIN. CODE ch.482A; CAL. CODE REGS. tit. 13, art. 3.7.

⁴⁹ Gabriel Weiner and Bryant Walker Smith, *Automated Driving: Legislative and Regulatory Action*, cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action.

⁵⁰ See California Department of Motor Vehicles, *Deployment of Autonomous Vehicles for Public Operation*, <https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto> (last accessed Jan. 6, 2015).

⁵¹ NEV. ADMIN. CODE § 482A.030.

⁵² CAL. VEH. CODE § 38750(a)(4); FLA. STAT. ANN. § 316.86.

⁵³ D.C. CODE § 50-2352(2).

⁵⁴ *Id.* § 50-2353; FLA. STAT. ANN. § 316.86(2);

⁵⁵ CAL. CODE REGS. tit. 13, § 227.22.

⁵⁶ *Id.*

⁵⁷ *Id.* § 227.20(a).

iii. Future legislative developments

In the future, it is likely that state statutes and regulations will be amended to regulate platooning, V2V communications in general, and automated low-speed shuttles. For now, these issues remain unaddressed. States are also likely to include new or enhanced liability provisions, licensing requirements, and provisions setting forth what automated vehicle operators may and may not do behind the wheel. A recent Nevada statute prohibiting the use of handheld wireless communication devices while driving, for example, specifically exempts automated vehicle operators from the prohibition.⁵⁸ It is likely that states will address this and similar issues in future legislative sessions.⁵⁹

The efficiency with which these issues will be addressed and the future regulation of AV use by private individuals likely depends on whether states grant state agencies the authority to promulgate regulations governing AV testing and use. California, Nevada, and Florida's statutes grant the state departments of motor vehicles broad authority to promulgate additional regulations governing automated vehicle testing and use.⁶⁰ As mentioned *supra*, California is already in the process of developing regulations governing automated vehicle use by the public. Michigan and DC, on the other hand, do not grant state agencies any particular authority to regulate automated vehicle testing and use; therefore, any changes must come from the state legislature. It is likely that Michigan and DC will be slower to allow automated vehicle use by the public as a result.

b. Federal statutes and regulations

Although states are the primary regulators of motor vehicle use, the federal government, through the Federal Highway Administration (FHWA) and the National Highway Transportation Safety Administration (NHTSA), supports state and local government regulatory efforts and promulgates statutes and regulations setting forth minimum safety requirements.⁶¹

The federal government has not yet issued binding statutes or regulations governing automated vehicle use in particular. At the moment, remains unclear when and to what extent the federal government will attempt to regulate automated vehicle testing or use. As NHTSA acknowledged in a May 2013 policy statement, "in light of the rapid evolution and wide variations in self-driving technologies, [the agency does] not believe that detailed regulation of these technologies is feasible at the federal or state level."⁶²

⁵⁸ NEV. REV. STAT. ANN. § 484B.165(7).

⁵⁹ See also Ryan Holeywell, *6 Questions States Need to Ask About Self-Driving Cars* (Aug, 13, 2013), <http://www.governing.com/blogs/fedwatch/gov-six-questions-that-need-to-be-answered-about-self-driving-cars.html>.

⁶⁰ CAL. VEH. CODE § 38750(d); NEV. REV. STAT. ANN. § 482A.100(1).

⁶¹ See, e.g., Federal Motor Vehicle Safety Standards and Regulations, 49 C.F.R. part 571.

⁶² NHTSA Preliminary Statement of Policy, at 11–12 (May, 2013), *available at* http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.

Some legal analysts predict that the federal government will wait to issue any regulations until states have had a chance to issue and their own regulations and work out any initial problems themselves.⁶³ Other analysts suspect that the federal government will not attempt to regulate testing, licensing, permitting, or driver training at all, as the federal government has suggested that these issues should be subject to state control alone.⁶⁴ The federal government may, however, issue regulations—and therefore preempt any existing state regulations—governing automated vehicle safety standards.⁶⁵

For now, NHTSA cautions states against authorizing the use of automated-vehicles for non-testing purposes. Automated vehicle technology, the agency cautions, “is not yet at the stage of sophistication or demonstrated safety capability that it should be authorized for use by members of the public for general driving purposes.”⁶⁶ If and when states do pass legislation permitting automated vehicle use for non-testing purposes, the NHTSA recommends that the states require a driver licensed to operate automated vehicles be seated in the driver’s seat and able to take over control of the vehicle at any time.

NHTSA’s May 2013 policy statement also includes number of suggestions intended to guide the regulation and testing of automated vehicle technology.⁶⁷ With respect to regulation, NHTSA recommends that:

- A. Regulators ensure on-road testing of self-driving vehicles minimize risks to other road users. This may mean, for example, that regulators require parties testing automated vehicles to certify that their automated vehicles have been tested for a certain number of miles before they can be used on public roads.
- B. Regulators require automated vehicles to be tested only in certain, pre-determined conditions. These conditions may include driving only on limited-access highways or low-traffic areas.
- C. Regulators establish reporting requirements that monitor automated vehicle performance. Specifically, the reporting requirements may require the collection of data regarding near-crashes or the number of times human drivers are prompted to take control.

With respect to testing, NHTSA recommends that:

- A. Testers ensure that it is easy for drivers to switch from self-driving mode to driver control in a “safe, simple, and timely” fashion.

⁶³ See, e.g., Andrew R. Swanson, “*Somebody Grab the Wheel!*”: State Autonomous Vehicle Legislation and the Road to A National Regime, 97 MARQ. L. REV. 1085, 1127 (2014) (“The NHTSA will establish rules and regulations covering autonomous vehicles, and these rules and regulations will supersede state regulations while having been informed by the state regulations that were in place at the testing stage.”).

⁶⁴ Risks of Federal Preemption, *supra* note 26 at 1.

⁶⁵ *Id.* at 1, 2–3.

⁶⁶ *Id.* at 14.

⁶⁷ NHTSA Preliminary Statement of Policy at 12–14.

- B. Test-vehicles are equipped with technology that enables them to tell the driver when the automated driving system has malfunctioned.
- C. Testers ensure that the installation of automated technology does not override any federally-required safety technologies.
- D. Testers make self-driving vehicles capable of recording information about how self-driving technology functioned (or malfunctioned) if an accident occurs.

As of May 2013, NHTSA was conducting research on Level 1 automation and had either begun or planned to begin research on Levels 2–4 in the near future.⁶⁸ NHTSA expected its research to focus primarily on 1) studying human-vehicle interaction, 2) establishing safety requirements for electronic control systems, and 3) developing system performance requirements.⁶⁹ NHTSA issued its Advance Notice of Proposed Rulemaking to Begin Implementation of Vehicle-to-Vehicle Communications Technology in August 2014.⁷⁰ The agency anticipates that these regulations, along with other pending research, will inform its decisions regarding how to regulate automation Levels 2–4.⁷¹

c. International conventions

International law plays at least a minor role in the regulation of automated vehicle use. International travel by automated vehicles is governed by the 1949 Geneva Convention on Road Traffic⁷² (hereinafter “the Convention”), which governs the cross-border use of automated vehicles. Whether the Convention governs the domestic use of automated vehicles remains an open question, however. Nor is it clear whether the Convention’s provisions are binding in American courts.⁷³ If the Convention does apply in the United States, it may limit automated vehicle use until Congress enacts legislation specifying that driverless vehicles are legal. Such legislation would likely trump the Convention’s requirements.⁷⁴

d. Other legal issues

Because automated vehicle use and the legal regimes that govern it are still relatively new, a number of questions remain unanswered and will likely continue to remain so for years to come. One question that legal analysts have considered is which party should assume liability if

⁶⁸ *Id.* at 6.

⁶⁹ *Id.* at 6–9.

⁷⁰ See NHTSA, “U.S. Department of Transportation Issues Advance Notice of Proposed Rulemaking to Begin Implementation of Vehicle-to-Vehicle Communications Technology” (Aug. 18, 2014),

⁷¹ *Id.* at 9. <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications>.

⁷² *Geneva Convention on Road Traffic, with Annexes & Protocol, Dated at Geneva Sept. 19, 1949*, T.I.A.S. No. 2487 (Mar. 26, 1952).

⁷³ See Smith, *supra* note 23, at 442 & 442 n.166.

⁷⁴ *Reid v. Covert*, 354 U.S. 1, 18 (1957) (setting forth the Last in Time rule, which holds that when treaties and statutes conflict, the one ratified or passed most recently trumps).

an automated vehicle does get into an accident. If, as in Michigan,⁷⁵ a statute requires a person to be in the driver's seat who can assume control of the vehicle at a moment's notice, that individual could be found responsible for any accident. But requiring passengers in an automated vehicle to be able to assume control at a moment's notice would obscure many of the benefits of automated vehicle technology. Eventually, the "legal operator" of an autonomous vehicle could include "a passenger, a remote supervisor, or no one at all."⁷⁶

Could liability, then, be placed on the upfitter? What if, for example, the individual in the driver's seat was expecting the car to alert him to assume control of the vehicle and he never received the alert? In that situation, he might have a reasonable argument that the programmer or upfitter should be held liable.⁷⁷ Although the upfitter might be able to argue that the passenger assumed at least some of the risk as soon as he purchased or agreed to ride in the automated vehicle, given that all vehicles—automated or not—carry some risk of malfunction,⁷⁸ it is likely that upfitter's ability to make this argument successfully will decrease as the level of automation increases. And if a court finds that an automated vehicle's faulty programming caused an accident, it may be more inclined to hold an upfitter strictly liable for the accident.⁷⁹

Other parties besides the passenger and upfitter may also factor into the liability analysis. For example, automated vehicle technology could harm non-passengers, even when the technology functions as it is supposed to. If an upfitter programs a car to protect its passengers at all costs, even when this might come at a cost to non-passengers like cyclists and pedestrians, the injured non-passenger may have a legal claim against the upfitter. Some analysts expect that upfitters may attempt to limit their liability in this situation by including warnings that alert passengers of the risks—to themselves and others—of riding in automated vehicles.⁸⁰

And if the City of Ann Arbor or the AAATA owns a fleet of vehicles, they too could be held liable for any accidents, just as they might be held liable for any accidents a city-owned bus might cause.

⁷⁵ See *id.* § 257.665(2).

⁷⁶ Bryant Walker Smith, *A Legal Perspective on Three Misconceptions in Vehicle Automation*, at 3 (Jan. 1, 2014) available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2459164.

⁷⁷ Jeffrey K. Gurney, *Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles*, U. ILL. J.L. TECH. & POL'Y, Fall 2013, at 247, 264 (addressing failure to warn claims); see also *id.* at 252 n.33 (collecting sources addressing tort liability and automated vehicles).

⁷⁸ For more on this issue, see *id.* at 247 (arguing manufacturers of automated vehicle technologies should only be liable for accidents caused in automated mode when the driver is either distracted or has diminished capacities).

⁷⁹ RESTATEMENT (SECOND) OF TORTS § 402A (1965); see also John Villasenor, *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation*, Brookings Institution, at 8 (Apr. 2014) available at http://www.brookings.edu/~media/research/files/papers/2014/04/products%20liability%20driverless%20cars%20villasenor/products_liability_and_driverless_cars (noting that "strict liability has been invoked with respect to manufacturing defects, design defects, and 'failure to warn.'").

⁸⁰ Brian Fung, *When Driverless Cars Crash, Who's To Blame?*, WASHINGTON POST (May 12, 2014)

<http://www.washingtonpost.com/blogs/the-switch/wp/2014/05/12/when-driverless-cars-crash-whos-to-blame/>

In short, the legal framework governing automated vehicle use is unsettled and may remain so for many years. (Realistically, after all, it will have to co-evolve with the technology and its actual use and impacts.) Despite Professor Smith’s optimistic prediction that automated vehicles are “probably legal in the United States,”⁸¹ a number of issues must be addressed before the technology can be used on a broad scale.

First, although Michigan has enacted automated vehicle legislation, the fact that its legislation remains limited to testing only leaves many questions open to speculation. It is likely, however, that as other states enact similar legislation and as testing continues, states will either answer these questions themselves or the federal government will enact a comprehensive regulatory scheme that supersedes most state legislation. Second, even with a comprehensive framework in place, the liability issues that will arise from widespread automated vehicle use will likely present difficult and novel legal questions that programmers and upfitters should consider, and courts will grapple with, for decades to come.

Research and outreach recommendations

- This paper addressed specifically the regulation of automated vehicles themselves. Further research on the local, state, and federal regulation of roadways and how regulation of these roadways may affect AV use should be completed.
- In that same vein, further research should also be completed on the difference between regulating automated vehicles as individual entities and regulating ACV systems, in which automated vehicles are not only connected to other vehicles, but also to a larger a cyber-infrastructure.
- Researchers should also pay close attention to California’s pending regulations governing not only the testing, but also the public use of automated vehicles. At the moment, Michigan law allows only testing. Although state legislators predict that statutes governing automated vehicle use will follow shortly, it is likely that such statutes will not be passed in Michigan for many years, and California’s approach to this issue may be instructive.
- Researchers should also anticipate ways to limit upfitter liability for any accidents automated vehicles cause. As discussed above, the Michigan statute includes a specific provision saddling liability on upfitters. It is unclear, however, whether there are any limits to this liability. Researchers should consider ways to limit upfitter liability, and may also consider how the statute could be amended to allocate liability more clearly. This issue will become particularly important when the operator of the car—a private person, for example—is no longer working for or otherwise associated with the upfitter and liability may therefore be assigned to entirely different entities.

⁸¹ Smith, *supra* note **Error! Bookmark not defined.**, at 412.

- Further research should also address the privacy concerns automated technology raises and find a way to prevent the hacking (and potential hijacking) of automated vehicles.

Public trust and consumer acceptance

Another major barrier to successful deployment of a demonstration fleet of ACVs in Ann Arbor is consumer acceptance. While Ann Arbor’s population may be more amenable to ACV technology than other cities based on its demographics, there are still significant hurdles to overcome. A 2014 UMTRI survey⁸² showed that 70.9% of US respondents had heard of autonomous or self-driving vehicles, and that 56.3% of US respondents had a “very positive” or “somewhat positive” opinion regarding autonomous vehicles. Specifically, US respondents seemed most optimistic about the safety benefits of autonomous vehicles, with the following percentages of respondents stating that the following benefits were “somewhat likely” or “very likely” to occur:

- Improved emergency response to crashes: 71.6%
- Reduced crash severity: 68.9%
- Fewer crashes: 67.8%

However, seemingly ironically, respondents also had the greatest concerns related to safety issues. When asked about their level of concern with riding in a Level 3 automated vehicle, 26.1% of US respondents stated that they would be “very concerned”, while increasing the level of automation to Level 4 increased the percentage of respondents would be “very concerned” to 35.9%. This likely reflects driver and passenger unease with the lack of driver controls in a Level 4 automated vehicle and the lack of ability of drivers to take over driving, with 60.1% of US respondents stating that they would be “very concerned” riding in a vehicle with no driver controls available, and with 35.5% of respondents who would choose to watch the road while riding in a Level 4 vehicle instead of a wide variety of other activities including reading, talking on the phone, watching TV, and sleeping.

A 2010 Accenture survey⁸³ was slightly less optimistic. In this survey, 51% of US and UK respondents stated that they would not feel comfortable using an autonomous vehicle. Of these, 48% stated that they would be encouraged to use autonomous vehicles if they could take back

⁸² Schoettle, B., and Sivak, M. (2014, Oct.). Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia. *University of Michigan Transportation Research Institute*.

⁸³ Accenture Research (2011, Jan.) Embedded software consumer pulse survey – Overall survey results presentation. Accessed on 11/29/2014. Retrieved from: <http://newsroom.accenture.com/images/20020/EmbeddedSoftwareOverall.pdf>

control if needed. Similarly, in a CarInsurance.com survey in 2013,⁸⁴ 75% of respondents thought they could drive a car better than a computer, and 64% stated that computers were not capable of the same quality of decision-making as human drivers. A 2013 survey by the Alliance of Automobile Manufacturers⁸⁵ showed that only 33% of consumers believed that fully autonomous vehicles were a good idea, 42% believed they were a bad idea, and 24% were undecided. However, in a 2013 Cisco survey,⁸⁶ about 60% of consumers stated that they would ride in a driverless car.

This rather scattered public reaction reflects the vagaries of surveying opinions on a technology that is as yet science fiction for the vast majority of respondents. The public is generally optimistic about the potential benefits of ACVs, and also quite concerned about potential safety hazards, the foremost being the inability of humans to take over driving when needed. These issues with consumer acceptance will need to be addressed through a strategic campaign of public education and demonstration of the technology in order to not only encourage ridership in the demonstration fleet, but also ensure that elected and appointed officials in the city support the rollout. One potential resource in understanding and overcoming perceptions of risk among Ann Arbor residents and potential ACV users is the University of Michigan's Risk Science Center. Their research could be particularly useful in understanding consumer perceptions of voluntary versus involuntary risk related to the presence of driver controls in ACVs.

Research and outreach recommendations

- While the data presented here represented the results of nationally-representative surveys, it would be beneficial to perform a representative survey within the city of Ann Arbor on consumer perceptions and trust of self-driving vehicles.
- Researchers should perform interviews with representatives from active community organizations, like the Ann Arbor Parent-Teachers Organization, to gauge their optimism and concerns towards ACV technology. These private meetings should be followed with public meetings to openly air concerns related to the technology and educate community members on the benefits and proven capabilities of the technology, as well as possible scenarios for deployment.

⁸⁴ Mearian, L. (2013, Nov. 6). 90% of drivers would consider an autonomous car if it cut insurance rates. *ComputerWorld*. Accessed on 11/29/2014. Retrieved from: <http://www.computerworld.com/article/2485672/emerging-technology/90--of-drivers-would-consider-an-autonomous-car-if-it-cut-insurance-rates.html>

⁸⁵ Johnson, A. (2014, Feb.). The impact of automated vehicle technology. *Fender Bender*. Accessed on 11/29/2014. Retrieved from: <http://www.fenderbender.com/FenderBender/February-2014/The-Impact-of-Automated-Vehicle-Technology/>

⁸⁶ Fitchard, K. (2013, May 14). Cisco survey: Consumers are getting comfortable with the idea of the driverless car. *GigaOm*. Accessed on 11/29/2014. Retrieved from: <https://gigaom.com/2013/05/14/cisco-survey-drivers-are-getting-comfortable-with-the-idea-of-the-driverless-car/>

Agreements with the city to install V2I infrastructure

Another potential barrier to deployment of ACVs in Ann Arbor is installing the necessary V2I communications equipment that would be required for vehicles to achieve self-driving capability. Fortunately, this process is already partially underway with the expansion of the Connected Vehicles Study to include 9,000 vehicles and the addition of basic V2I communication infrastructure along major corridors throughout the city.⁸⁷ However, V2I infrastructure will have to be improved and expanded greatly in order to accommodate any level of self-driving technology. This would require the approval and cooperation of the city government.

This process could present challenges as the city considers the short-term costs of installation, long-term maintenance costs, and the risk of liability.⁸⁸ The city may even be hesitant to spend time discussing the issue and planning for deployment if they do not see tangible benefits resulting from the project. The city may also be wary of entering in to any agreement where they could be liable for the malfunctioning of any V2I communications equipment. Unless the University is prepared to completely cover the cost of installing, monitoring, and maintaining the V2I communications equipment, it may be challenging to present a compelling business case to the city as to why they should invest in this infrastructure for a demonstration fleet. However, the necessity of monitoring the performance of V2I infrastructure presents its own set of challenges in that the city may be concerned with data security if they were to allow the University to access data related to the operations of its communications infrastructure.

Ultimately, while the city has been relatively cooperative on the Connected Vehicles study, it is unclear how they will react when more expansive investments are needed in V2I infrastructure and when such infrastructure will actually have safety implications. MTC will need to continue building relationships with city officials, particularly more skeptical members of City Council who would likely need to approve any contract between the University and the city. MTC must also work on highlighting the specific and tangible benefits that could arise from investing in comprehensive V2I infrastructure for the demonstration fleet to both transportation-oriented city planners and members of City Council. Additionally, in order to gain the critical mass of City Council support necessary to invest in V2I infrastructure, the ACV demonstration should provide improved transportation services to a relatively wide geographic area representing multiple City Council wards,⁸⁹ as opposed to focusing solely on the downtown or University area.

⁸⁷ Woodhouse, K. (2014, April 17). U-M is turning Ann Arbor into the world's largest lab for wireless vehicle communication. *MLive*. Accessed on 11/29/2014. Retrieved from: <http://www.mlive.com/news/ann-arbor/index.ssf/2014/04/transportation.html>

⁸⁸ Sayer, James. (2014, June 2). University of Michigan Transportation Research Institute. Telephone interview.

⁸⁹ There are 5 total city council wards in Ann Arbor with 2 Council Members each.

Research and outreach recommendations

- MTC should perform interviews with city planners and members of City Council to gauge their reactions to the idea of ACV deployment in Ann Arbor and identify potential allies and opponents.
- MTC should then work with potential allies to identify the steps necessary to secure investment in V2I infrastructure and develop a plan to maintain the integrity of that infrastructure.
- MTC should then collaborate with allies in city government and City Council to present plans for V2I infrastructure installation and maintenance to potential opponents.

Conservative transit planning and funding

As discussed in “Opportunities for deployment” below, it is possible that the Ann Arbor deployment fleet may be partially or fully owned by AAATA, and another significant barrier to any deployment where the vehicles would be owned and operated by AAATA is that the project would be subject to a relatively conservative and slow-moving planning and funding process which requires the cooperation of a large number of stakeholders. This process has recently been on display with The Ann Arbor Connector,⁹⁰ which is a proposed high-capacity, north-south transit project to meet rising demand between North and Central Campus and encourage commuters to avoid driving to downtown. AAATA, Michigan Parking and Transportation Services (PTS), the City of Ann Arbor, and Ann Arbor Downtown Development Authority (DDA) have partnered to advance The Connector.

The Connector project, which is still far from complete, arguably began in the 1980s, when a study of the Fuller/Glen/Geddes Corridor proposed a high-capacity rail line to connect north and south Ann Arbor.⁹¹ In 2006, Mayor John Hieftje published the Model for Mobility, which contained his proposed vision for future transportation and transit options into and through Ann Arbor. It proposed an East-West Regional Commuter Rail service, today referred to as the “Detroit Connector”, as well as a North-South Regional Commuter Rail service, today referred to as the Washtenaw and Livingston Line Rail Project (WALLY), and saw The Connector as a means to “connect” these two proposed projects.⁹² In 2009, the City of Ann Arbor, AATA, Michigan PTS, and DDA agreed on a cost-sharing arrangement to perform the Connector feasibility study,⁹³ which was published in 2011. After the publication of the feasibility study, the

⁹⁰ URS Corporation (2011, Feb. 21). Ann Arbor Connector Feasibility Study – Final Report. Accessed on 11/29/2014. Retrieved from: <http://www.aconnector.com/documents/feasibility-report.pdf>

⁹¹ White, Christopher. (2014, Oct. 16). Ann Arbor Area Transportation Authority. Personal interview.

⁹² Cooper, Eli. (2014, Oct.1). City of Ann Arbor. Personal interview.

⁹³ Coburn, B. (2010, June 14). Transit connector study: Initial analysis. *The Ann Arbor Chronicle*. Accessed on 11/29/2014. Retrieved from: <http://annarborchronicle.com/tag/north-south-connector/>

Connector stakeholders were successful in securing a Federal Transit Administration (FTA) grant to cover 80% of the costs of an alternatives analysis.⁹⁴ However, obtaining the remaining 20% of the funding from the city only occurred after a 5-4 City Council vote to place the alternatives analysis on the October 2012 City Council agenda.⁹⁵ ⁹⁶ Since the agreement to fund an alternatives analysis, the Connector stakeholders engaged in a series of public input meetings,⁹⁷ and the Connector alternatives analysis is ready to be publicly released as of the end of 2014.⁹⁸

This process highlighted a number of potential institutional barriers facing any large-scale transit project in Ann Arbor. The Connector's momentum has been due in large part to the possibility of federal funding to supplement local outlays. FTA and its Congressional appropriators may be wary of approving requests for funding to implement a demonstration fleet of relatively unproven technology. Furthermore, the availability of any type of FTA funding is perennially uncertain, given that Congress must pass new authorizing legislation ("Highway Bills") to fund major new infrastructure improvements. Estimating the availability of federal funding years in the future proves challenging and would depend on the party composition of the House and Senate, since Republicans tend to be less favorable toward devoting significant public funding to transit projects.⁹⁹

Given this challenging environment, it may be advisable for the steering committee of the Mobility Transformation Center to devote significant energy toward educating the FTA and relevant Congressional committees about the need to establish a funding stream for experimental transit projects. It may also be advisable to investigate the availability of alternative funding streams, such as corporate partners interested in gathering operational data regarding ACVs.

Research and outreach recommendations

- MTC should identify all potential federal funding sources for improved transportation projects, including those available through FTA and NHTSA, and analyze trends in the nature and availability of these funding sources over time

⁹⁴ Federal Transit Administration (2011, Oct. 17). Alternatives analysis project descriptions. Accessed on 11/29/2014. Retrieved from: http://www.fta.dot.gov/documents/AA_Descriptions-Final.pdf

⁹⁵ Stanton, R.J. (2012, Sept. 5). Mayor John Hieftje to Ann Arbor Connector project opponents: 'Just show a little bit of vision'. *The Ann Arbor News*. Accessed on 11/29/2014. Retrieved from: <http://www.annarbor.com/news/city-council-likely-to-reconsider-vote-against-ann-arbor-connector-project-at-next-meeting/>

⁹⁶ Bologna, G., and Wizner, T. (2012, Oct. 16). Council approves funding for second phase of transit study. *The Michigan Daily*. Accessed on 11/29/2014. Retrieved from: <http://www.michigandaily.com/news/council-approves-funding-second-phase-transit-study>

⁹⁷ Pruitt, J. (2013, Feb. 3). Area Residents Support Light-rail System Serving Ann Arbor. *The Ann Arbor Journal*. Accessed on 11/29/2014. Retrieved from: http://www.heritage.com/articles/2013/02/03/ann_arbor_journal/news/doc510efc09cb3aa764565234.txt

⁹⁸ Cooper, Eli. (2014, Oct.1). City of Ann Arbor. Personal interview.

⁹⁹ Nader, J. (2012, Feb. 6). GOP's Transportation Bill Would Eviscerate Mass Transit Funding. *TheHill*. Accessed on 11/29/2014. Retrieved from: <http://thehill.com/blogs/congress-blog/economy-a-budget/208937-rep-jerrold-nadler-d-ny>

AAATA approval process

Under rollout scenarios where AAATA owns the fleet, another potential barrier to AAATA ownership and operation of the ACV demonstration fleet is the future makeup of the nine-member AAATA board, eight of whom are appointed by the Ann Arbor Mayor and approved by the City Council. AAATA board members serve 5-year terms and are responsible for policy development, meaning they would certainly be involved in any decision to replace buses with smaller ACVs on less-traveled routes.¹⁰⁰ While AAATA is a relatively technical organization with a board devoted to expanding public transit services, they also have a history of making relatively cautious and pragmatic decisions when operating and maintaining services. This is demonstrated by their recent decision to purchase only three hybrid-electric buses out of a total of 27, given that federal funding was not available to pay the difference in price between conventional diesel buses and hybrid buses.¹⁰¹ This indicates that the AAATA board will need assurance of both tangible benefits and external funding sources in order to take on the risk of participating in the ACV demonstration.

Research and outreach recommendations

- MTC should interview representatives from AAATA to gauge interest in ACV technology and potential concerns related to AAATA ownership and operation of ACVs.

Time horizon

Finally, the Connector process highlighted that time is a major barrier to the deployment of an AAATA owned and operated ACV fleet. Serious work on the Connector project began in 2006, and eight years later, the Connector stakeholders are only now ready to release an alternatives analysis. It is important to keep in mind that it has taken this long to make progress on a project for which there is proven technology and a very demonstrated transportation need, particularly the 50,000 daily person trips between North and Central Campus and the strain that this creates on the AAATA and U-M fixed route bus services. If MTC would like to partner with AAATA to implement an ACV demonstration fleet, they must begin building relationships now and putting the concept of vehicle automation on AAATA's radar.

¹⁰⁰ Ann Arbor Area Transportation Authority (2014). Board of Directors. Accessed on 11/29/2014. Retrieved from: <http://www.theride.org/AboutUs/Leadership/BoardofDirectors>

¹⁰¹ Stanton, R. (2014, Nov. 21). AAATA board agrees to pay \$586K extra to purchase 3 hybrid buses in latest order. *MLive*. Accessed on 11/29/2014. Retrieved from: http://www.mlive.com/news/ann-arbor/index.ssf/2014/11/aaata_board_agrees_to_pay_586k.html

Downtown parking availability

Another barrier to the effective deployment of a shared ACV demonstration fleet is the availability of relatively inexpensive parking in the downtown area. Currently, there are a total of 8,249 public parking spots operated by the Downtown Development Authority in downtown Ann Arbor: 6,041 spots in parking garages, 385 in metered lots, and 1,823 metered street spots. As of October 2014, there were 4,505 monthly parking permits issued for public garages and lots downtown, indicating that a significant percentage of drivers who use the lots are long-term parkers who commute in and out of downtown frequently. The price of a monthly parking permit currently ranges from \$140/month to \$195/month, or about \$6.67 to \$9.29 per weekday, assuming about 21 weekdays per month.¹⁰² Additionally, at least 60 businesses validate parking for their customers in downtown garages and structures.¹⁰³ This availability of low-priced downtown parking for short- and long-term creates a disincentive to using public transit to travel downtown. In order to encourage ridership in shared ACVs, MTC might need to work with DDA to develop parking policies and pricing that encourage the use of public transportation and discourage solo driving and parking downtown.

Research and outreach recommendations

- MTC should interview representatives from DDA to gauge their interest in ACV technology, concerns with the technology, and their potential willingness to reduce parking availability in downtown Ann Arbor.
- In its survey of Ann Arbor residents, MTC should ask specifically how residents would feel about reducing parking availability in Ann Arbor if improved ACV transit options were available.

Labor resistance to vehicle automation

Another potential barrier to introducing shared ACVs in Ann Arbor is the potential labor resistance. Any deployment option that involves driverless vehicles owned and operated by AAATA faces the threat of backlash from the Transportation Worker's Union Local 171, which represents AAATA bus drivers, maintenance workers, and information specialists.¹⁰⁴ The union has effectively used its bargaining power in previous negotiations with AAATA—the union has

¹⁰² Morehouse, J. (2014, Nov. 25). Personal communication. *Ann Arbor Downtown Development Authority*.

¹⁰³ Ann Arbor Downtown Development Authority (2014, Oct.) Businesses that validate parking in the downtown area as of October 2014. Accessed on 11/29/2014. Retrieved from: <http://www.a2dda.org/wp-content/uploads/transportation/October-2014-Validating-Businesses-List.pdf>

¹⁰⁴ Ann Arbor Area Transportation Authority (2014). Leadership. Accessed on 11/29/2014. Retrieved from: <http://www.theride.org/AboutUs/Leadership>

either threatened to strike or has actually gone on strike during contract negotiations in 1975,¹⁰⁵ 1980,¹⁰⁶ and 2007.¹⁰⁷ The union could prove to be an obstacle to deployment of driverless technology within AAATA's fleet by threatening to strike and creating negative media attention.

Similarly, the taxi lobby in Ann Arbor has shown its ability to flex political muscle. While the number of registered taxis in Ann Arbor is small (139 as of 2013),¹⁰⁸ they were able to work through the city's taxicab board to encourage the city attorney to issue cease and desist letters to competitors Uber and Lyft in May 2014.¹⁰⁹ This shows that the local taxi industry is willing to get politically involved when they feel their industry and employment is threatened. However, while successful in issuing cease and desist letters, Uber and Lyft continued to operate within the city without receiving citations,¹¹⁰ and in September 2014, City Council agreed by a vote of 8-3 to direct the city administrator to negotiate operating agreements with the ridesharing companies.¹¹¹ Furthermore, the mayor-elect of Ann Arbor, Christopher Taylor, has publicly expressed support for expanding ridesharing services like Uber and Lyft.¹¹² Therefore, while the taxi lobby may be able to draw public attention to issues that threaten their industry, they may not be successful in swaying city officials to support their interests over others.

Research and outreach recommendations

- Pending the results of Ann Arbor public opinion surveys and outreach to active community organizations, MTC should encourage allies of the deployment to contact City Council members and the mayor to express their support for the test fleet.

C. Opportunities for deployment

Given the social and institutional hurdles described above, the overarching goal of the ACV demonstration fleet in Ann Arbor should be to test and document the safety of ACV technology. It is highly likely that large-scale deployment of ACVs could significantly improve

¹⁰⁵ Harris, G. (1975, Dec. 5). Bus drivers turn down AATA contract offer. *The Ann Arbor News*. Accessed on 11/29/2014. Retrieved from: <http://oldnews.aadl.org/node/86679>

¹⁰⁶ The Toledo Blade (1980, July 2). Ann Arbor, Ypsilanti residents' bus service halted by strike. Accessed on 11/29/2014. Retrieved from:

<http://news.google.com/newspapers?nid=1350&dat=19800702&id=9hNPAAAAIIBAJ&sjid=owIEAAAAIIBAJ&pg=6266,2883761>

¹⁰⁷ MLive (2007, July 17). AATA workers picket, demand contract meeting. Accessed on 11/29/2014. Retrieved from:

http://blog.mlive.com/annarbornews/2007/07/aata_workers_picket_demand_con.html

¹⁰⁸ Askins, D. (2014, Sept. 15). Personal communication. *The Ann Arbor Chronicle*.

¹⁰⁹ Allen, J. (2014, May 16). Uber, Lyft rideshare services issued cease and desist letters by city of Ann Arbor. *MLive*. Accessed on 11/29/2014. Retrieved from: http://www.mlive.com/business/ann-arbor/index.ssf/2014/05/uber_lyft_rideshare_services_i.html

¹¹⁰ Allen, J. (2014, July 7). Uber, Lyft ignore Ann Arbor's cease and desist demand; no tickets issued following city's orders. *MLive*. Accessed on 11/29/2014. Retrieved from: http://www.mlive.com/business/ann-arbor/index.ssf/2014/07/uber_lyft_ignore_ann_arbors_ce.html

¹¹¹ Ann Arbor Chronicle (2014, Sept. 2). Ann Arbor to pursue deals with Uber, Lyft. Accessed on 11/29/2014. Retrieved from: <http://annarborchronicle.com/2014/09/02/ann-arbor-to-pursue-deals-with-uber-lyft/>

¹¹² Kerr, E. (2014, Oct. 21). Mayoral candidates aim to keep young talent in Ann Arbor. *The Michigan Daily*. Accessed on 11/29/2014. Retrieved from: <http://www.michigandaily.com/article/taylor-announces-plan-keep-university-grads-ann-arbor>

mobility, particularly for underserved populations who either lack access to, or cannot operate, a private vehicle. Such a fleet could also reduce greenhouse gas and other harmful emissions through electrification¹¹³ and vehicle right-sizing. However, these benefits can only be realized by first achieving safety and securing public confidence in ACV technology. This means that an initial deployment of a demonstration fleet may not realize immediate benefits for the underserved or for the environment. However, focusing on demonstrating the safety benefits of the technology would pave the way for larger scale deployment of such technology in Ann Arbor and other communities by encouraging consumer acceptance of the technology, spurring the development of a more robust legal and regulatory framework around ACVs, and providing real-world data on the costs and benefits of deploying ACV technology.

Opportunities for Level 3 automation

When considered carefully, the value added of Level 3 technology is quite small, particularly for any type of commercial or public service application. Without the ability of the vehicle to handle all safety-critical functions of driving, it would still be necessary for a driver to be in place, ready to take control of the vehicle at all times (similar to trains and airplanes). The technical details surrounding the timing and type of warning a driver that would be presented during extreme weather events and unexpected occurrences is still unclear, making it difficult to assess whether drivers will be able to effectively and legally multitask while operating a Level 3 ACV. Thus it is also questionable whether legislators and regulators would legally permit the sort of multi-tasking that would enable companies to reduce costs by eliminating unnecessary labor.

Private household ownership

Despite the path-dependency issues outlined in this paper's "Perils of Automation" section, we recognize that one of the options that might be explored for deployment of Level 3 ACVs is to allow for private household ownership of individual vehicles that are equipped by Vehicle to Vehicle (V2V), V2I, and self-driving capabilities. This model would represent an extension of the Connected Vehicles study, although the technology would likely have to be installed in the vehicle at the time of purchase. Once vehicles are sold with the necessary technology, MTC would need to make arrangements to regularly collect data from the vehicles.

It is possible that certain households in Ann Arbor may see value in having Level 3 automated technology that takes control of driving in most situations. The common characteristic among these households is that at least one driver would likely spend the majority of their transportation time within the Ann Arbor city limits, where they would benefit from the driverless technology. We used microdata from the 2013 American Community Survey¹¹⁴ to

¹¹³ Assuming that the future electricity generation mix includes more low-emission sources like wind, solar, and natural gas.

¹¹⁴ U.S. Census Bureau (2013). Ann Arbor (city), Michigan. American Community Survey 2013 Estimates. Accessed on 11/29/2014. Retrieved from: <http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t>

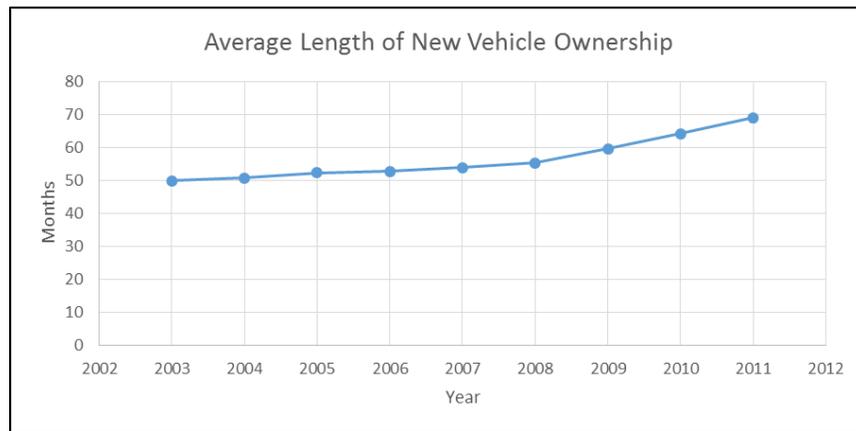
identify mutually-exclusive categories of households that might be interested in owning such technology. The first category consists of households that own at least one vehicle and have at least one adult working in or close to Ann Arbor who regularly drives to work. There are approximately 20,600 households in Ann Arbor that fall in this category. The second category consists of households where one adult does not work and has access to a vehicle. This category includes households where at least one adult is a “stay-at-home” mother or father. Approximately 6,900 Ann Arbor households fall into this category. The final category consists of households that own at least one car and have at least one adult who is retired. Approximately 5,400 Ann Arbor households fall into this category. This leaves a total of approximately 32,900 Ann Arbor households that may gain consistent benefits from owning a Level 3 automated vehicle and being to operate in driverless mode for most of the time within the Ann Arbor city limits.

However, not all of these households are in the market for a new vehicle. According to the 2013 Consumer Expenditure Survey,¹¹⁵ of the vehicles currently owned by households across the US, approximately 38.3% were purchased new. Furthermore, of the households that may purchase new vehicles, the average length of ownership of new vehicles has been steadily increasing, rising from approximately 49.8 months at the beginning of 2003 to 71.4 months at the end of 2011.¹¹⁶ This means that as of the end of 2011, approximately 16.8% of households that own a new vehicle might be in the market to replace their vehicle. Considering these figures, of the 32,900 households in Ann Arbor who might benefit from owning Level 3 technology, about 2,100 households would be purchasing a new vehicle each year, assuming that the percentage of new versus used vehicles purchased and the length of vehicle ownership remain roughly the same. These assumptions may not be sound, since the length of new vehicle ownership has consistently increased since 2003 while the introduction of revolutionary ACV technology may change certain consumers’ timeline for replacing older vehicles.

¹¹⁵ U.S. Department of Labor, Bureau of Labor and Statistics (2013). *Consumer Expenditure Survey, 2013: Interview Survey and Detailed Expenditure Files*. Accessed on 11/29/2014. Retrieved from: <http://www.bls.gov/cex/pumhome.htm#current>

¹¹⁶ IHS Automotive (2012, Feb. 21). U.S. Consumers Hold on to New Vehicles Nearly Six Years, an All-Time High. Accessed on 11/29/2014. Retrieved from: https://www.polk.com/company/news/u.s._consumers_hold_on_to_new_vehicles_nearly_six_years_an_all_time_high

Figure 9: Average Length of New Vehicle Ownership



Source: IHS Automotive (2012, Feb. 21). U.S. Consumers Hold on to New Vehicles Nearly Six Years, an All-Time High. Accessed on 11/29/2014. Retrieved from: https://www.polk.com/company/news/u.s._consumers_hold_on_to_new_vehicles_nearly_six_years_an_all_time_high

Therefore, this leaves a maximum of about 2,100 households per year who may be interested in purchasing a Level 3 automated vehicle. However, not all of these households will perceive value from owning such a vehicle. Some may distrust the technology and not be interested in purchasing it at all, and some may see value in the technology but not be willing to pay extra for it. According to UMTRI survey research,¹¹⁷ only about 44% of US respondents were interested in owning or leasing a self-driving vehicle. Granted, this question asked about owning a Level 4 automated vehicle, and the percentage of those interested in owning a Level 3 vehicle may be higher since a driver could still take control of the vehicle. Similarly, 54.5% of US respondents stated that they would not be willing to pay any extra to own a driverless vehicle. If these figures on consumer acceptance remain the same, only about 900 Ann Arbor households may be interested in purchasing a new self-driving vehicle each year, and it is unclear how much these households would be willing to pay for such technology. Additionally, some households in Ann Arbor may not expect to live in the city in the long-term and might resist investing in a vehicle with Ann Arbor-specific automation technology if they plan to move out of the city.

Additionally, if these vehicles were to be purchased by individual households, MTC would need to build functional partnerships with local auto dealers representing a wide variety of automakers. The auto dealers would be charged with a number of difficult tasks to ensure the rollout occurs successfully. First, they would need to be trained to determine customer eligibility to buy a Level 3 vehicle and participate in the demonstration fleet rollout. They would also need to be equipped and motivated to “sell” the technology and the benefits of participating in the test fleet to their customers. They would also need to be well-versed in the capabilities and limits of the Level 3 technology and be able to communicate these limits effectively.

¹¹⁷ Schoettle, B., and Sivak, M. (2014, Oct.). Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia. *University of Michigan Transportation Research Institute*.

Short-term rental car companies

Another potential market for vehicles with Level 3 technology is short-term rental fleets like Zipcar. Longer term rental fleets like those owned by rental companies such as Hertz, National, and Enterprise are not considered because the likelihood that these vehicles will be driven outside the city limits is quite high. Perhaps the greatest benefit for a company like Zipcar could be reduced insurance rates if the Level 3 technology performed better on the road than a human driver. This would be especially attractive if these reduced rates compensated for the increased cost of a vehicle with Level 3 automation with a relatively short payback period. However, it is unlikely that insurance companies would immediately recognize the reduction in risk and lower rates, particularly for a demonstration test fleet.

Another potential benefit could be the ability of a car to reposition itself after the end of use. Instead of a customer having to return the car to a designated lot, the car could potentially relocate itself traveling at a low speed. This, of course, would require supporting legislation and regulation that would allow a car to operate without a driver. With Level 3 automation, such permission would likely be contingent on limited speeds and timeframes (such as late at night when there are few road users active). This may create a higher willingness to pay among late-night customers who would prefer not to have to bring a car back to the lot.

However, even the market for short-term rentals is difficult due to the lack of a compelling business case for investing in Level 3 vehicles. It is unclear whether Zipcar customers would be willing to pay extra to rent a car equipped with such technology, making it potentially difficult for the company to pass along the extra costs of automation to the customer. Unless this risk were heavily subsidized or lower insurance rates compensated for technology costs, it seems unlikely that a company like Zipcar would incur the risk of investing in such technology when it is unclear how much consumers will value the technology and be willing to pay for it.

Another potential complication with using short-term rentals for a demonstration fleet is customers' unfamiliarity with the technology and long intervals between driving. If drivers were to own the vehicle and use it daily or at least several times per week, they would become more accustomed to driving with the Level 3 automated technology, be more inclined to use it, and be more familiar with the capabilities and limits of the technology. For an infrequent Zipcar user, trying to figure out how to use the automation technology properly and becoming accustomed to paying attention while the vehicle is driving itself may prove intimidating or burdensome, which may lead some drivers to completely override the technology and not use it at all. Even worse, drivers who are unfamiliar with the capabilities of the technology may over-rely on it and reduce the overall safety of their driving. There is evidence that overtrust in automation technology can reduce driver safety and potentially contribute to crashes.¹¹⁸ Therefore, in order to effectively deploy Level 3 automation in short-term rentals, MTC and rental companies would

¹¹⁸ Itoh, M. (2012). Toward overtrust-free advanced driver assistance systems. *Cognition, Technology, and Work* 14: 51-60.

have to develop effective strategies to educate drivers on the limits of the technology and encourage drivers to use the technology as much as possible without overly relying on it.

Slow-Speed Pod Cars

Another option with Level 3 technology might be driverless pod cars that operate at very slow speeds (approximately 12 mph or less) around areas with a lot of foot traffic. Such technology already exists - a French company called INDUCT is marketing a fully driverless vehicle called Navia that does not exceed 12.5 mph and is designed for use in large public spaces like airports, university and business campuses, and stadiums.¹¹⁹ INDUCT is currently developing partnerships with Ecole Polytechnique Federale de Lausanne in Geneva, Switzerland, and Pole Sante Sud in Le Mans, France to introduce their pod cars on their campuses.¹²⁰ Perhaps a more ambitious initiative is that being undertaken in the city of Milton Keynes in the UK. Milton Keynes is introducing 3 pod cars that will travel in a designated lane on the sidewalk at a maximum speed of 12 mph to ferry passengers from the rail station to the city center, which is a distance of a little over a mile. Pending the trial's success, the city plans to introduce 100 pod cars by 2017 that will travel with pedestrians on the sidewalk instead of in a designated lane.¹²¹

There may be options for introducing such vehicles on streets or sidewalks in Ann Arbor. Potential candidate locations could be University of Michigan's Central Campus, North Campus, Medical Center, or a restricted zone in downtown Ann Arbor. However, these options seem unattractive for a demonstration fleet rollout for several reasons. Milton Keynes is a relatively new city that was designed with plenty of space for pedestrian travel, which allows ample space for the pod cars to operate on sidewalks and pedestrian paths. Ann Arbor's downtown was not designed in the same way, and there may not be enough space on sidewalks for the pod cars to operate. Additionally, one could anticipate significant political resistance to introducing such vehicles in pedestrian areas on the U-M campus - it may not be aesthetically pleasing to many University students, faculty, and alumni if the Central Campus Diag were overrun by driverless pods. Finally, if the vehicles were to operate solely in pedestrian-only areas, their value as part of a demonstration test fleet is questionable, since one of the main goals of the demonstration is to test the technology's viability on roadways with other vehicles.

This leaves the option of having the vehicle operate at slow speeds on Ann Arbor city streets. This could be viable given that many downtown and campus streets are fitted with bike lanes that provide a corridor for slower traffic. However, this could present safety challenges and contribute to increased congestion since the vehicles travel so slowly and share the road with

¹¹⁹ Zolfagharifard, E. (2014, Jan. 7). World's first commercial driverless car goes on sale – but it only reaches a top speed of 12 mph. *Daily Mail*. Accessed on 11/29/2014. Retrieved from: <http://www.dailymail.co.uk/sciencetech/article-2535117/Worlds-commercial-driverless-vehicle-goes-sale-reaches-12mph.html>

¹²⁰ INDUCT (no date). Navia – the 100% electric automated transport. Accessed on 11/29/2014. Retrieved from: <http://induct-technology.com/en/products/navia-the-100-electric-automated-transport>

¹²¹ Wakefield, J. (2014, Oct. 1). Tomorrow's cities: Towards the congestion-free city. *BBC News*. Accessed on 11/29/2014. Retrieved from: <http://www.bbc.com/news/technology-28106814>

full-sized, human-operated vehicles. It is also currently illegal for motor vehicles to operate in bike lanes, so having any pod car operate in them in downtown Ann Arbor would require amending Michigan's Complete Streets legislation (Public Acts 134 and 135 of 2010).¹²²

Finally, it is unclear whether there would be significant demand to use such a service within relatively compact areas. The transportation need in Milton Keynes is clear given that many commuters enter the city by train and need to travel on foot over a mile to the city center. However, there does not exist a similar environment in Ann Arbor, and it is highly possible that offering an alternative to traveling a short distance on foot would be viewed as little more than a novelty that could create a traffic nuisance. Therefore, it is not clear how much people who currently travel short distances on foot would be willing to pay to travel the same short distance in a driverless pod. This raises the question of which entity would be the best candidate to own the vehicles. Given the uncertainty of consumer demand and willingness to pay, it appears unlikely that a private company would assume the risk of purchasing a fleet as part of a test demonstration. If the vehicles operated largely around U-M's Central Campus, North Campus, or Medical Center, then ownership by Michigan PTS would make sense. PTS has shown willingness to invest in improved transportation on and between University campuses, as demonstrated by its investment of \$160,000 in the Connector feasibility study¹²³. However, if the vehicles were concentrated in Ann Arbor's downtown, then the most likely candidate would be AAATA, which would present similar challenges to those described in the "Barriers" section above.

Designated right-of-way

One option considered was a restricted right-of-way (ROW) system where vehicles could operate in designated lanes. This could reduce the potential hazard of ACVs operating with non-ACVs, pedestrians, and cyclists, and potentially allow for Level 3 automated vehicles to operate in the city without a driver. However, we considered this option infeasible largely because there exists little room on Ann Arbor roadways for such designated lanes. The map in Figure 10 shows which roadways in Ann Arbor are currently at least four lanes wide, which we assume would be the width necessary to have a designated lane running each direction. It shows that relying on designated lanes for ACV would leave large swaths of the city unserviceable by ACVs. Furthermore, as the city continues to perform upgrades on existing roadways, it is likely that some of these currently 4-lane roadways may be converted to 2-lane roadways with a center lane and bike lanes, in accordance with the city's non-motorized transportation plan.¹²⁴ This would further limit the space available for designated lanes for ACVs.

¹²² Michigan Department of Transportation (no date). What every Michigan driver should know about bicycle lanes. Accessed on 11/29/2014. Retrieved from: http://www.michigan.gov/documents/mdot/MDOT_Bicycle_Lane_Brochure_402819_7.pdf

¹²³ Coburn

¹²⁴ City of Ann Arbor (2013, November 18). City of Ann Arbor Non-motorized Transportation Plan Update 2013. Accessed on 11/29/2014. Retrieved from: <http://www.a2gov.org/Documents/Ann%20Arbor%20NTP%20Update%202013.pdf>

Figure 10: Map of Multi-Lane Roadways within Ann Arbor City Limits



Last-mile goods delivery

Another option that would likely be infeasible without Level 4 automation is last-mile goods delivery or courier service. At Level 3 automation, the vehicle would not be able to control all safety critical functions 100% of the time, which would make it necessary to have a driver ready to take control of the vehicle at all times. This would greatly increase the cost of delivery service, since the company would have to pay both a premium for the automated and connected technology, but also continue paying a driver. Additionally, at Level 3 automation, it is unlikely that the driver could use the time while the vehicle is driving itself to perform other work and achieve currently undiscovered efficiencies, since the driver must be ready to take control of the vehicle at all times. Unless installing Level 3 automation could somehow reduce insurance rates for a delivery company's drivers and vehicle fleet, it is unlikely that these companies would see the benefits of Level 3 technology outweighing the costs.

Research and outreach recommendations

- Analysis of increased willingness-to-pay for currently marketed driver assistance technologies, like adaptive cruise control, and potential willingness to pay for Level 3 ACV technology.
- Potential leasing arrangements that may overcome the barriers associated with private household ownership of Level 3 ACVs.

- Outreach to Ann Arbor area auto dealerships to analyze actual number of new car sales and leases per year, as well as to identify barriers to auto dealer implementation of targeted ACV sales.
- Analysis of the pricing structure of short-term rental companies like ZipCar, as well as outreach to representatives from short-term rental companies to gauge their interest in ACV technology.

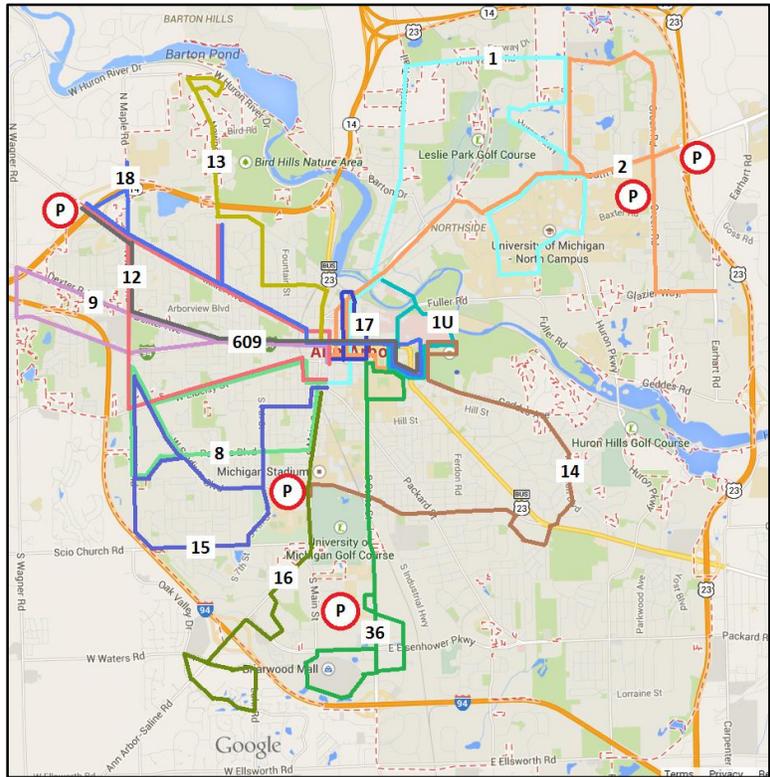
Opportunities for Level 4 automation

When automation advances from Level 3 to Level 4, the value added of the technology increases substantially, especially for commercial and public transport applications. Level 4 automation would allow for the removal of a driver from all driving situations, significantly reducing the cost of commercial or public transport. It would also allow vehicles to operate without designated lanes and would allow vehicles to reposition themselves automatically without an occupant present. This level of automation would also remove problems arising from driver complacency and overtrust that may result from Level 3 automation technology. Note that the options identified here may not be entirely ready for completely driverless deployment during the initial stages of the test fleet rollout. However, depending on the availability of funding, these options could be tested at Level 3 capability with a driver present and gradually scaled up to completely driverless Level 4 capability as their systems are de-bugged and improved.

Small vehicle transit service on AAATA routes

With Level 4 automation, we identified the most attractive option for the demonstration fleet rollout as a series of smaller, driverless pod cars to replace buses on less-traveled AAATA routes that lie within the Ann Arbor city limits. Such a system has the potential to positively impact both riders on those routes as well as AAATA. Additionally, installation of V2I communications equipment along these select routes would be much less capital-intensive than trying to install V2I equipment across the city. Figure 11 shows a map of each route that lies mostly within the Ann Arbor city limits. Because the infrastructure improvements to accommodate ACV technology lie only within the city limits, we did not consider routes such as the 4, 5, or 6 that travel well outside of Ann Arbor. This map shows that these routes service a relatively wide area in the city, as well as a number of park and ride lots for commuters coming in from outside the city, and could improve mobility to a large number of transit users.

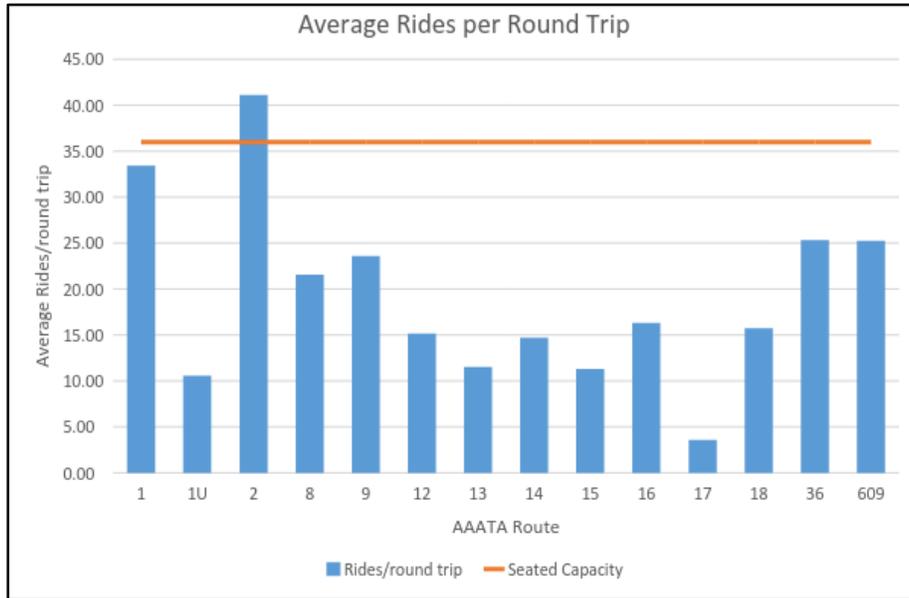
Figure 11: Ann Arbor-specific AAATA bus routes



Source: Ann Arbor Area Transportation Authority (2014). System Map and Route Schedule PDFs. Accessed on 11/29/2014. Retrieved from: <http://www.theride.org/SchedulesMapsTools/MapRoutePDFs>

Currently, as shown in Figure 12, the average number of rides per round trip for many of the Ann Arbor bus routes falls well below the seated capacity of a full-size bus. Furthermore, the seated capacity does not represent the full capacity of the bus, since there is ample standing room to allow for up to 60 passengers. Operating full-size buses on these routes during non-peak hours with such low ridership is quite inefficient and leads to the unnecessary consumption of fuel. Furthermore, because AAATA is limited to using full-size buses on these routes, waiting times for the bus to arrive can be quite long, and many of these routes are not in service at night or on weekends.

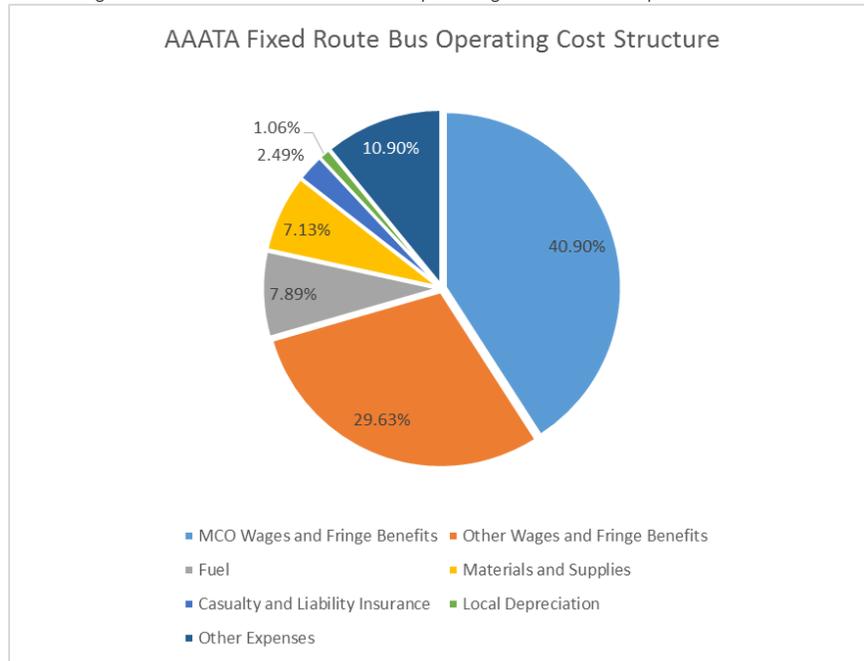
Figure 12: Average Rides per Round Trip on Select AAATA Routes



Sources: Ann Arbor Area Transportation Authority (2013). Performance Report: October – December 2013. Accessed on 11/29/2014. Retrieved from: <http://a2gov.legistar.com/LegislationDetail.aspx?ID=1635000&GUID=09A79313-3C08-4DDA-890A-1C4D3492127B&Options=&Search=>

AAATA currently operates full-size buses on these routes instead of smaller buses or vans because it is not cost-effective to tailor the size of the vehicle to the expected ridership at any given time. As shown in Figure 13, approximately 40.9% of the cost per service hour of operating an AAATA bus (or \$51-52 per service hour) consists of bus driver wages and fringe benefits. This amount would remain roughly fixed even if the bus driver were to instead operate a van or smaller bus. Furthermore, drivers must work relatively stable shifts and cannot be called at the last minute to meet an increase in demand. This makes operating a full-size bus at designated time intervals more practical, because the same driver can accommodate a wide variety of travel demand volume at a lower price than a team of drivers who drive vans or small buses only as needed. Additionally, one of the main benefits of operating a small bus or van instead of a full-size bus is increased fuel efficiency. However, given that fuel currently comprises only about 7.9% of the operating cost per service hour of a full-size bus, the potential savings made possible by increasing fuel economy would not compensate for the significant additional cost of having more drivers on hand to meet peak demand with small buses or vans.

Figure 13: AAATA Fixed Route Bus Operating Cost Structure per Service Hour



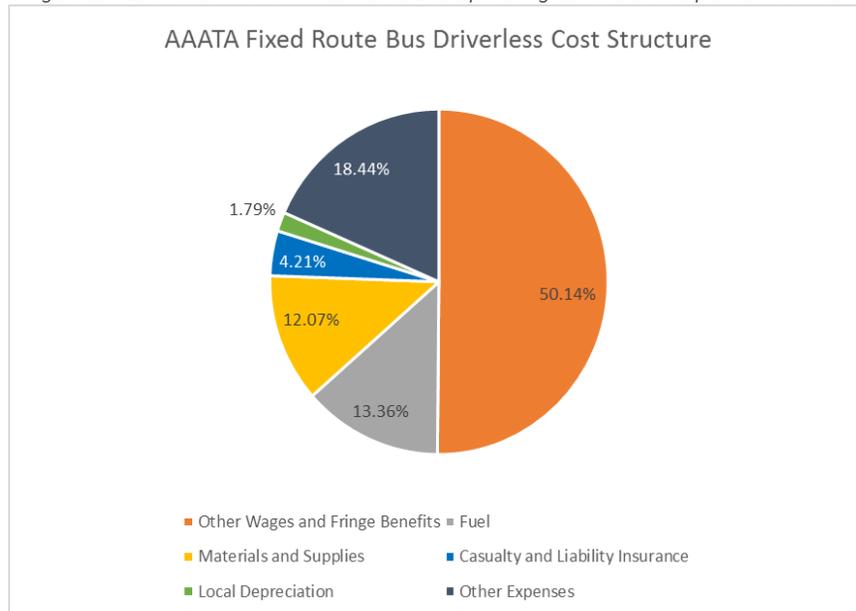
“MCO” refers to “Motor Coach Operator”.

Source: Ann Arbor Area Transportation Authority (2014, Sept. 29). FY 2015 Operating Budget. Accessed on 11/29/2014.

Retrieved from:

<http://www.theride.org/Portals/0/Documents/5AboutUs/5.3.5%20TheRide%20FY%202015%20Adopted%20Operating%20Budget.pdf>

Figure 14: Estimated AAATA Fixed Route Bus Operating Cost Structure per Service Hour



Source: Ann Arbor Area Transportation Authority (2014, Sept. 29). FY 2015 Operating Budget. Accessed on 11/29/2014.

Retrieved from:

<http://www.theride.org/Portals/0/Documents/5AboutUs/5.3.5%20TheRide%20FY%202015%20Adopted%20Operating%20Budget.pdf>

The ability to make vehicles driverless could significantly expand opportunities to provide more efficient and convenient mass transit on less-traveled fixed routes. For one, fuel economy could be improved by operating smaller vehicles and increasing ridership as a proportion of vehicle capacity. Second, operating smaller vehicles would allow vehicles to travel at greater frequency than full-size buses during peak periods, which would significantly decrease the wait time for riders. Third, during off-peak periods, vehicles could travel on-demand instead of on a fixed time schedule either by calling the bus via a smartphone application or perhaps pushing a button at a designated bus stop. During off-periods, vehicles could wait at either end of the route either in a Park and Ride lot or in a public parking garage or lot in the downtown area. This increase in convenience for riders could incentivize more riders to use the system, which would decrease the number of cars traveling to and parking in congested areas downtown and decrease GHG emissions per commuter. Figure 14 shows the estimated operating cost structure of a driverless vehicle, which makes the business case for operating smaller vehicles on these routes much more compelling. It is important to note that these cost estimates are imperfect, given that implementation of a driverless vehicle fleet would likely require an increase in wages in other areas like maintenance and general administration, as well as materials and supplies.

Research and outreach recommendations

- Detailed analysis of hour-by-hour ridership on select AAATA routes operating within the Ann Arbor city limits to identify opportunities for replacement of full-size busses with smaller, on-demand ACVs.
- Outreach to AAATA to determine the feasibility and costs of system overhauls to accommodate a mixed ACV/bus fleet, as well as to better understand how this fleet redesign would change the revenue and cost structure of AAATA.

On-demand, shared taxi ACVs

A much more advanced option for deployment of ACVs with Level 4 automation would be a shared taxi-on-demand system that would operate throughout the city. This example largely reflects the model envisioned by Burns, *et al.* (2012),¹²⁵ where passengers could order a taxi using an app on their smartphone, input their destination, and a right-sized, driverless pod would ferry them to their destination either privately or with other passengers traveling in the same direction.

However, we consider this model to be difficult for the demonstration fleet rollout for several reasons. First, it seems unlikely that the city could install the scale of V2I communications infrastructure necessary for a driverless shared-taxi ACV fleet to operate everywhere within the city limits. We deem it necessary for the taxi to be able to operate everywhere within the city

¹²⁵ Burns, L., *et al.* (2013). Transforming personal mobility. *The Earth Institute – Columbia University*.

limits because potential riders may become frustrated if they are forced to remember the specifics of where the taxis do and do not operate within the city and may abandon the service in favor of other modes of transportation. Second, the significant societal benefits and improvements in mobility resulting from the shared taxi fleet depend on having a relatively large fleet – Burns, *et al.* estimate approximately 18,000 vehicles in order to ensure wait times of less than one minute. If only 2,000 vehicles were deployed as part of the fleet, it is not clear how long wait times would be and how well the fleet could accommodate peak demand during morning and evening rush hours (although this challenge could be mitigated by restricted membership).

Somewhat ironically, another issue is the current lack of demand for such a shared taxi service. As of 2013, there were only 139 registered taxis in the city.¹²⁶ While there are also a number of Uber and Lyft drivers that operate in the area (Uber and Lyft do not publicly disclose the number of drivers they have in each urban area), it is unlikely that there are currently enough riders to create demand for 2,000 shared taxis. Despite having higher numbers of commuters that use alternative modes of transportation to travel to and from work than peer cities, Ann Arbor still has a relatively high rate of vehicle ownership (approximately 0.9 vehicles/adult).¹²⁷ Additionally, while a well-functioning shared taxi service may encourage some riders who currently use fixed-route bus services to use the shared taxi service instead, this could be a tough sell for many bus riders given the low cost of ridership. Regular fares are currently set at \$1.50 for fixed route services.¹²⁸ While the number of riders who ride for free as a result of AAATA's partnerships with the University of Michigan, Eastern Michigan University, Washtenaw Community College, and DDA is not readily available, an estimated 35.9% of AAATA's passenger revenue will come from such contracts in FY 2015,¹²⁹ suggesting that a relatively high percentage of riders currently use fixed-route bus services for free. This low cost of ridership would discourage many passengers from regularly using a shared taxi service, no matter how convenient, if it could not deliver the ambitious cost savings envisaged by Burns et al, or if the same organizations that provide free bus service would also provide free shared ACV service. Therefore, it seems very difficult for the demonstration fleet rollout to be a shared taxi service that could operate point-to-point anywhere in the city.

¹²⁶ Askins, D. (2014, Sept. 15). Personal communication. *The Ann Arbor Chronicle*.

¹²⁷ U.S. Department of Labor, Bureau of Labor and Statistics (2013). *Consumer Expenditure Survey, 2013: Interview Survey and Detailed Expenditure Files*. Accessed on 11/29/2014. Retrieved from: <http://www.bls.gov/cex/pumhome.htm#current>

¹²⁸ Ann Arbor Area Transportation Authority (2014). Fares & Passes. Accessed on 11/29/2014. Retrieved from: <http://www.theride.org/FaresPasses>

¹²⁹ Ann Arbor Area Transportation Authority (2014, Sept. 29). FY 2015 Operating Budget. Accessed on 11/29/2014. Retrieved from: <http://www.theride.org/Portals/0/Documents/5AboutUs/5.3.5%20TheRide%20FY%202015%20Adopted%20Operating%20Budget.pdf>

Research and outreach recommendations

- Build relationships with rideshare companies like Uber and Lyft to try to determine the number of Uber and Lyft drivers operating in the city, as well as the average number of riders at different times of the year. This will be difficult, because Uber and Lyft are notoriously secretive with their data.
- Continue to collaborate with Louis Merlin to identify appropriate mixtures of on-demand taxis and public transit to maximize the efficiency and availability of transit within Ann Arbor.

Last-mile goods delivery

With Level 4 automation, goods delivery becomes slightly more feasible because there is no longer a need for a driver to be ready to take control of the vehicle. This significantly frees up time for the occupant of the vehicle to focus instead on preparing the next delivery, filling out paperwork, and performing other tasks while in transit, allowing the occupant and company to achieve undiscovered efficiencies.

However, options with Level 4 automation remain limited for several reasons. First, having to operate entirely within the Ann Arbor city limits significantly constrains operations. Two of the largest local courier companies operating in Ann Arbor – Metro Delivery¹³⁰ and Rightaway Delivery,¹³¹ both provide service well outside of the city limits, and large couriers like FedEx and UPS likely do not have delivery trucks that operate only within the city limits. Second, many deliveries are made with large box trucks or tractor-trailers, and automating these vehicles may contribute to public distrust towards introducing automated vehicle technology in large vehicles.¹³² While this may be a viable option in the future, it seems an unfit candidate for a demonstration fleet rollout. Third, while it would be possible to eliminate the driver, which would significantly cut costs, there are few delivery services that would not still require an occupant in the vehicle. For instance, a pizza delivery would still require an occupant to get out of the vehicle and bring the pizza to the customer's door. Therefore, the value added of automated vehicle technology for such delivery companies is realized only when the occupant can focus on other necessary tasks instead of driving.

Opportunities here could be mail or parcel delivery, where workers could sort and organize their parcels during their drive instead of while stopped. However, as discussed above,

¹³⁰ Metro Delivery (2014). Delivery services. Accessed on 11/29/2014. Retrieved from: <http://www.metrodelivery.com/delivery-services/>

¹³¹ Rightaway Delivery (2014). Accessed on 11/29/2014. Retrieved from: <http://www.rightawaydelivery.com/about-rightaway-delivery-service.html>

¹³² Schoettle, B., and Sivak, M. (2014, Oct.). Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia. *University of Michigan Transportation Research Institute*.

most large parcel services do not operate trucks exclusively within the city of Ann Arbor. Additionally, USPS has faced declining revenues and is expected to continue to face operational challenges.¹³³ This, combined with the necessity of obtaining federal funding to make large-scale investments in new technology, may limit their ability to replace mail truck fleets with automated vehicles. Therefore, goods delivery at this point is not a terribly attractive option for the demonstration fleet rollout.

The CityMobil2 deployment in La Rochelle presents circumstances under which last mile goods delivery would provide a much more synergistic match with a demonstration fleet. After years of issues due to congestion, noise pollution, and emissions in La Rochelle's busy city center, the city introduced access restrictions. Trucks are only allowed to enter the city center before 11 AM and may not exceed a total weight of 7.5 tons. The city utilizes "last mile" electric delivery trucks to deliver parcels to businesses in the center, and also pick up parcels from those businesses to distribute outside of the center. With the deployment of the CityMobil2 fleet, automated electric vehicles will be joining the mix of delivery trucks¹³⁴. If Ann Arbor experiences a similar shift towards a more regulated downtown, the goods delivery option may also become a more attractive option for the 2020 fleet rollout.

Research and outreach recommendations:

- Outreach to same-day delivery companies, parcel delivery companies, and USPS to gauge their interest in ACV technology, as well as the degree to which their vehicles operate entirely within Ann Arbor city limits.

Emergency service vehicles

Another option that would likely be infeasible for the demonstration fleet rollout would be emergency services like police, fire, and ambulance. Here, the benefits of Level 4 automation are clear. Police officers could fill out reports and more actively scope out their beat while riding in a vehicle instead of driving. Firefighters could assemble and prepare gear while on the way to a fire instead of having to prepare everything ahead of time. EMTs could save precious time by moving a patient immediately into an ambulance and having the ambulance drive itself to the hospital while both EMTs attended to the patient, instead of having to perform all two-person work on site and then have one EMT drive to the hospital. And in all these situations, a Level 4 automated vehicle would presumably be able to drive more safely at higher speeds than a human. However, because the demonstration fleet is meant to demonstrate the safety benefits of ACV technology to a potentially distrustful public and in an uncertain legal and regulatory

¹³³ McKenna, F. (2014, November). Industry Report 49111 – Postal Service in the US. *IBISWorld*.

¹³⁴ Nair, Stéphanie, and Auomated. "Cities Demonstrating Automated Road Passenger Transport." CityMobil2 (2012): 2012 <http://www.citymobil2.eu/en/upload/Deliverables/PU/D8.1_LaRochelle.pdf>

environment, it seems ill-fitting for such technology to be initially deployed in vehicles that would be undertaking the most dangerous and complex maneuvers on the road.

IV. Conclusion

The development of automated and connected vehicle technology brings with it the potential to radically transform our transportation system and vastly improve mobility services and environmental outcomes. However, ACV technology deployed on the wrong path presents huge potential environmental costs in the form of transportation rebound and increased fuel consumption. The ultimate goal for ACV technology deployment should thus be a shared vehicle model that can reduce carbon emissions and travel costs through automation, electrification, and vehicle right-sizing.

In its efforts to deploy a demonstration fleet of ACVs in Ann Arbor to provide proof of concept of the technology, the University of Michigan's Mobility Transformation Center must assess the technical, political, legal, regulatory, and administrative feasibility of various models of deployment. It must also consider these models' implications for the environmental, economic, and social health of both the Ann Arbor community and others who may seek to follow Ann Arbor's lead, and the potential for path dependence that each model creates. This report is a step towards scoping many of these issues, but significantly more research is necessary.

Ann Arbor is blessed with a number of enablers that facilitate a successful ACV demonstration fleet rollout, including:

- City size;
- Population characteristics;
- Technical sophistication of the University and planners within the city government and AAATA; and
- Brick-and-mortar testing facility where future users could see the technology in action.

Other communities in Europe are also testing various levels and uses of automated vehicle technology, providing valuable lessons from which MTC and Ann Arbor can learn.

However, there also exist a number of troubling barriers to the effective deployment of ACV technology in Ann Arbor:

- Michigan's legal and regulatory environment currently restricts the testing of driverless vehicles on public roads;

- Numerous unresolved questions around the liability and insurance implications of ACVs;
- Significant public distrust towards completely driverless vehicle technology; and
- Ann Arbor's conservative and slow local transit planning process.

Based on these enablers, barriers, and the characteristics of transportation in Ann Arbor, we analyzed several options for ACV deployment depending on the level of automation. We identified the most attractive option for deployment as a fleet of Level 4 driverless small buses or vans that could supplement Ann Arbor's existing AAATA bus system and replace full-sized buses on less-traveled routes. This model could improve personal mobility within the city, particularly for households without access to a private vehicle, and could improve the environmental impacts of AAATA's bus service. It would also serve as an important proof of concept for a model of mobility that favors shared ACV use instead of private household ACV ownership.

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Appendix A: Resources of Interest

Resource	Website
Ann Arbor Area Transportation Authority	http://www.theride.org/
Ann Arbor Transportation Planning	http://www.a2gov.org/departments/systems-planning/Transportation/Pages/Transportation%20Planning.aspx
CityMobil2: Cities Demonstrating Automated Road Passenger Transport	http://www.citymobil2.eu/en/
Program on Sustainable Mobility, Earth Institute, Columbia University	http://sustainablemobility.ei.columbia.edu/
Stanford Law School: The Center for Internet and Society, Autonomous Driving	http://cyberlaw.stanford.edu/our-work/topics/autonomous-driving
University of Michigan Mobility Transformation Center	http://www.mtc.umich.edu/
University of Michigan Transportation Research Institute (UMTRI)	http://www.umtri.umich.edu/

Appendix B: Acronyms

AAATA – Ann Arbor Area Transit Authority
 AAMVA – American Association of Motor Vehicle Administrators
 ACV - Automated/Connected Vehicles
 AV – Automated Vehicle
 DDA – Downtown Development Authority
 FHWA – Federal Highway Administration
 FTA – Federal Transit Authority
 NHTSA – National Highway Traffic Administration
 PTS – Parking and Transportation Services
 ROW – Right-of-Way
 UMTRI – University of Michigan Transportation Institute
 V2I – Vehicle-to-Infrastructure
 V2V – Vehicle-to-Vehicle