Connected and Automated Vehicles: Urbanization versus Suburbanization

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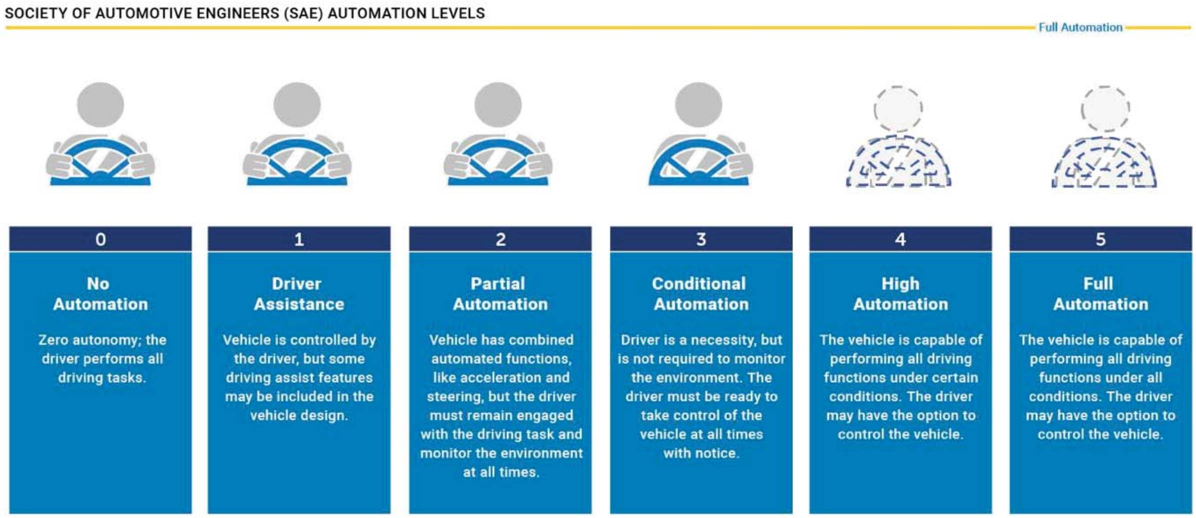
Testing has begun on fully connected and automated vehicles (CAVs). Within a decade or two, fully automated vehicles will be on public roads. Just as the automobile played significant role in changing the way people lived, so too will CAVs. However, that role is still unclear. CAVs, also known as self-driving vehicles, can lead a new wave of suburbanization, urbanization, or a mixture of both. To best prepare for the intended and potentially unintended consequences of CAVs, the federal, state, and local governments must be proactive in steering CAVs towards sustainable growth.

Introduction

Just over a century ago, advancement in transportation technology began to aid people in reshaping the way they lived their lives. As the automobile became more immersed in society during the 20th century, people were given the tool they needed to move out of the city and into the suburbs where housing and land prices were cheaper. We are now nearing the introduction of a new transportation technology - the automated vehicle. Connected and automated vehicles, also known as self-driving cars, were once only imaginable in science fiction. Now, we need to analyze and prepare for how automated vehicles are going to change the way we live our lives. If regulations are not implemented at both the state and federal level, the proliferation of autonomous vehicles could lead to a new wave of unsustainable suburbanization.

Levels of Automation

There are 6 levels, 0-5, of connected and automated vehicles (CAVs) identified by the Society of Automotive Engineers. Level 0 is no automation. Most vehicles today fall into this category, where the driver performs all driving related tasks. Level 1 vehicles have some driver assistance features like adaptive cruise control, but the driver is still in control of all driving tasks. Partial automation occurs at level 2. This is currently the highest level achieved by commercially available CAVs. Tesla's Autopilot is an example of a level 2 CAV currently available to consumers. Level 3 includes conditional automation. In these vehicles, a driver is required, but they are not needed to monitor the environment. The driver always must be ready to take control of the vehicle. High automation occurs at level 4. At this level, the vehicle can perform all driving related functions. These vehicles can only operate in certain conditions and still may need the driver to take control. Full automation is achieved at level 5. Here the vehicle can perform all driving functions in all environments and the passengers are nothing more than passive occupants ("Automated Vehicles for Safety", 2018). These levels are further explained in Figure 1.



Timeline for connected and automated vehicles

Important to the discussion about how CAVs will impact the urban and suburban environments is the timeline for adoption. Projections for a date when fully automated vehicles will be on the road have been wide ranging. One of the first major attempts to identify when CAVs are going to be on the road came from Morgan Stanley, an investment bank and financial services corporation, in 2013. Morgan Stanley estimated that self-driving vehicles would reach full market saturation in the mid 2020s (*Autonomous Cars*, 2013). Full market saturation is the point at which CAVs will be ubiquitous. As we near 2020, it is clear to see that Morgan Stanley's estimate was far too optimistic. Reasons for the delayed timeline will be outlined later in this paper.

Given the complexity of not only manufacturing level 4 and 5 CAVs but also rolling them out on public roads, industry experts have been hesitant to set a hard deadline for their prediction. These complexities include accident liability, technology costs, data privacy, federal and state regulations, safety, limited weather operability, and high definition mapping. McKinsey and Company, a global management and consulting firm, predicted in 2016 that CAVs will reach market saturation between 2040 and 2050 ("Automotive Revolution", 2016). In 2018, the Victoria Transport Policy Institute predicted market saturation to occur around the 2060s (Litman, 2015). Other estimations from industry experts tend to fall into the range of 2040 to 2060 for automated vehicles to reach market saturation. Auto manufacturers have begun making their own estimations for when they will be releasing their self-driving cars. Alphabet Inc.'s subsidiary Waymo, which has also logged the most miles testing CAVs, has the earliest prediction. At the beginning of 2018, they announced their plan to have a ride-sharing fleet of level 4 automated vehicles by the end of 2018 (Huddleston, 2018). In December 2018, Waymo carried through with their prediction. Waymo's One Program now provides an automated ride-sharing service to a limited number of customers in and surrounding Phoenix, Arizona (Huddleston, 2018). General Motors anticipates releasing their first level 4 CAV in 2019 for ride sharing services (Hawkins, 2018). Ford predicts that their level 4 ride sharing service vehicle will not be ready until 2021 (Golson, 2018).

Barriers to Implementing CAVs

Self-driving vehicles are immensely complicated technology. As such, they face barriers to their widespread implementation. These barriers include high definition mapping, accident liability, privacy, and costs. This is not a comprehensive list of barriers, but following sections outline some primary barriers that

CAVs face.

High Definition Mapping

Connected and automated vehicles face several challenges that will slow down the timeline for their widespread use. First, level 4 and 5 automated vehicles require high definition (HD) maps in order to function. These maps enable CAVs to know their location and understand their environment (Hook, 2018). The construction of HD maps is a significant obstacle that must be overcome before high level CAVs can hit the road. Companies such as Waymo, Uber, HERE, Tesla, Lyft, Civil Maps, and others are trying to be the first to perfect the mapping process. As of now, the process is time consuming, expensive, generates more data than current infrastructure can properly handle, and requires a high degree of computing power from within the vehicle itself (Barnes, 2018).

Liability

The legal question of liability must also be solved. When an automated vehicle gets into a car accident, either the CAV user or the manufacturer will have to assume the liability in an accident. The significant difference between level 1-3 and 4-5 CAVs is also an issue. In a CAV level 3 or below, users cannot be fully disengaged from the vehicle. It would be reasonable to claim that the user would assume liability in an accident if they ignored safety and warning features within the vehicle. In a level 4 or 5 CAV, the user can be more disengaged. In this case, it must be determined who assumes the liability for an accident. These are all questions that have to be resolved before CAVs can become commercially available and operated on freely on public roadways.

Privacy

Privacy is another concern. The technology used in CAVs collects and transmits a plethora of data not only about the vehicle itself, but also the user. Information collected can include biometric data like height, weight, and voice tone. Further analysis of the data can reveal information about personal health, travel habits, and specific locations visited (Barnes, 2018) If proper security measures are not in place, these data can be harvested by third-parties.

Cost

A final example is cost. Due to the technology and advanced computing involved in CAVs, it is estimated that an additional $10,000 premium will be added on to automated vehicles on top of their prices currently (Fagnant, 2015). This price will eventually fall, but the first commercially available fully automated vehicles are likely to be well out of the price range of most Americans. For comparison, Audi's 2019 A8 sedan, which contains partial level 3 technology, starts at nearly $92,000. The base model, without this technology, starts at approximately $84,000 ("Luxury found the vehicle it deserves", 2018).

History of Transportation Technology Shaping Suburbanization

Suburbanization in America during the 20th century, where the population shifted from urban areas and into less densely populated suburbs, was driven by several factors, including advancements in transportation technology. The diffusion, or widespread use, of the automobile in American society during this period was concurrent with the expansive wave of suburbanization (Kopecky, 2010). As transportation travel expenses declined, those who were able to afford having an automobile were able to move to the urban edge where housing was cheaper. Due to the cost, by 1910 only approximately 2% of American households owned an automobile. However, as costs began to rapidly fall, 44% owned a car by the mid-1930s. By the 1970s, just over 80% of Americans owned at least one car (Kopecky, 2010).

While use of the automobile grew during the 20th century, so too did the U.S. metropolitan population. Between 1910 and 2000, the metropolitan population grew from 28% to 80%. Most of this growth was seen in the suburbs, not central cities. Approximately half of the U.S. population resided in suburban areas by 2000 (Hobbs, 2002). As the 20th century came to an end, 4 out of 5 people in the U.S. now lived in metropolitan areas. At the same time, central city populations fell below 1950 levels as more people were moving into the suburbs (Hobbs, 2002). It is clear that the advent of the car was not the sole driving force of suburbanization in the 20th century. However, it is important to understand the role played by the automobile in that suburbanization to anticipate the impact of autonomous vehicles in the future. The automobile opened previously unfathomable and unfeasible options for the American people, so too will the autonomous vehicle.

Impact of CAVs on the Urban and Suburban Environment

Connected and automated vehicles have to the potential to significantly alter the urban and suburban dichotomy. These vehicles will change the value of travel time, increase safety, decrease congestion, change parking demand, and change the way we think about urban spaces.

Value of Travel Time

First, CAVs will dramatically change the value of travel time by reducing the opportunity cost of traveling. Automated vehicles, those at level 4 and 5, require little to no involvement from the passenger(s). As such, the passenger of the vehicle can use their travel time in a productive manner. For example, one hour spent driving can now be used to do work, homework, sleep, eat, or even shop online. Since individuals can use their commuting time in a productive manner, they may be more willing to commute even longer distances. This results in more people moving further into the suburbs where they can find lower housing prices (Litman, 2018) (McDonald, 2016).

Congestion

Connected to the change in the value of travel time is potential changes to congestion. According to the 2015 Urban Mobility Scorecard from Texas A&M's Transportation Institute, congestion in the United States is going to cause approximately 8.3 billion hours of delayed travel time and waste 3.8 billion gallons of fuel. This results in a total economic loss of $200 billion to the United States economy (Schrank, 2015). Connected and automated vehicles have the potential to reduce motor vehicle accidents and smooth traffic merging, both of which will help to alleviate traffic congestion between 15% and 60%. Just a 15% reduction in congestion would equal a national cost savings of $30 billion from fuel and time saved (Fagnant, 2015). By alleviating the cost of congestion, both in terms of time and money, CAVs further lessen the burden of long commutes or extended travel.

Safety

In the United States there are roughly 5.5 million reported motor vehicle accidents and 33,000 fatalities every year. Human error is the cause of over 90% of these accidents (Fagnant, 2015). These crashes result in an estimated loss of $250 to $300 billion per year (Blincoe, 2015). While it is difficult to quantify the exact impact of autonomous vehicles, it is clear that CAVs will reduce the number of accidents, fatalities, and financial cost of motor vehicle accidents. It is important to note that autonomous vehicles are not immune to accidents. Even though CAV accidents will occur, they will happen at a much lower frequency than accidents today. With increased safety, reduced congestion, and a lower opportunity cost of traveling, people will be more willing to travel longer distances. This opens the potential for a new wave of suburbanization.

Parking

Automated vehicles are also going to have an impact on urban communities. Self-driving vehicles are expected to impact parking demand in urban centers. Vehicles, on average, only spend 5% of their lifetime in motion. The other 95% is spent parked (Kockelman, 2017). Automated vehicles will likely spend more of their lifetime in motion. For a commuter, rather than driving to work and leaving their vehicle in the parking lot nearby, the car can be sent back to their home to service the next family member or remain there until it is needed again.

Alternatively, the vehicle can be sent to a free or reduced-price parking space outside of the city. As CAVs continue to be introduced into ride-sharing markets, the number of required parking spaces in densely developed areas will decrease. These vehicles can move from passenger to passenger without needing to spend a substantial amount of time parked. Additionally, the increasing prevalence of ride sharing services, paired with autonomous vehicles, could reduce the number of multi-vehicle households. Fewer households with multiple cars will result in a lower demand for urban parking. Automated vehicles can also utilize smaller parking spaces than those currently available. A properly designed parking lot or redesigned parking garage could accommodate up to 62% more vehicles than a conventional lot (Nourinejad, 2018). Decreased parking demand, coupled with increased efficiency and capacity of new or existing parking infrastructure, will generate a smaller parking footprint, especially in urban areas (Barnes, 2018).

Urban Design

After parking demand has been diminished, precious real estate in city centers can be reclaimed by local municipalities because that space is no longer needed for expansive parking lots. This real estate can then be utilized for a variety of purposes. It can be reclaimed as a shared community space, utilized for pedestrian infrastructure, turned into green space, or rezoned for an entirely new purpose (Skinner, 2016). Rezoning will allow local governments to take advantage of mixed-use development, also known as live-work space. This space blends residential, commercial, and entertainment uses. An example of this development would be a multi-story urban building where the first floor is comprised of commercial businesses while the upper floors contain residential units. Particularly, municipalities can invest in higher density residential buildings. With more housing and the reduced need for a car, urban centers may become more of an attractive place to live.

The Next Generation: Urbanization or Suburbanization?

The living preferences of the next two generations are going to be a substantial influence on whether CAVs usher in the next wave of suburbanization. As already identified, automated vehicles can drive the trend in either direction. By altering the value of travel time, CAVs can enable more individuals to move out of urban centers and into fringe communities. On the other hand, the way CAVs will alter urban living could attract more individuals to life in urban centers. An analysis of generational housing preferences is necessary to determine what, if any, public policies are needed to ensure sustainable growth. Without proper planning, unfettered suburbanization can lead to excessive travel with longer commutes, increased pollution associated with increased vehicle travel, increased usage and wearing down of public infrastructure, and the destruction of green space and disruption of natural habitats for further suburban development.

Housing Preferences

Millennials, loosely defined as individuals born between 1981 and 1996, are about to set the housing market precedent for years to come (Dimock, 2018). However, uncertainty surrounds their preferred housing option. Some studies have pointed to millennials abandoning the suburbs and adopting life in the city. Other studies claim that millennials will largely follow in the steps of their baby-boomer parents and move to the suburbs. Research conducted by Transportation Research Board shows that millennial living preferences will not be dramatically different from previous generations. The researchers conducted a comprehensive travel and residential survey in seven major cities in the United States. They found that the net migration of millennials trends toward suburban environments (Clewlow, 2017). In a 2013 survey, researchers determined that millennials preferred to live in “compact, mixed use, walkable, and transit accessible communities” (Moos. 2018). These characterizes are more representative of urban, not suburban, living. While there have been substantial efforts to study the housing desires of millennials, not enough research has been complied on their habits as it relates to autonomous vehicles. According to most industry experts, autonomous vehicles are not going to reach market saturation for another 40 to 60 years. Assuming adoption happens as soon as 40 years from now, most millennials will be over 60 years old. By that time, most will already be settled into either an urban or suburban lifestyle and nearing retirement. Given substantial student debt, rising costs of living, and stagnant wages, it is unlikely that a statistically significant number of millennials will be able to personally own an autonomous vehicle until CAVs become more widely used. Most individuals, not just millennials, will be unable to afford a CAV in the near future. However, if testing continues on operating CAVs in urban centers for ride sharing purposes, there will be a greater incentive for millennials to move into the city and abandon their car instead of moving further out into the suburbs. So, individually owned CAVs are unlikely to have a significant impact on Millennials until much later in their lives. If CAV use in ride-sharing becomes more prevalent, which is a current unknown, then CAVs may encourage more Millennials to move into urban areas.

Generation Z comes after millennials. These individuals are more likely to have their housing preferences significantly influenced by CAV technology than millennials. Unfortunately, little scholarly work has been dedicated to analyzing their housing preferences due to their age. These individuals are just entering college or are even younger.

Recommendations

Connected and automated vehicles have the capability to drive both suburbanization and urbanization. While it is important to understand the preferred housing options of future generations, not enough research exists to date. As such, state and local governments must be proactive in steering growth in a sustainable way. Sustainable growth involves preventing urban flight. Urban flight involves large populations of people abandoning urban centers and moving into suburban communities. Enough information exists now to conclude that automated vehicles will be an inescapable part of our reality. To not consider the impacts that CAVs will have on urban and suburban planning is irresponsible.

First, more research must be dedicated to determining the housing trends of Millennials, Generation Z, and the generation that will follow next. Understanding these trends will help determine what public policy initiatives will be the most successful producing the desired behavior or outcome.

Cities should take on this research to determine how best to attract the next generations and keep them from moving into the suburbs. Some of these methods include proactively starting to rezone urban centers and allow for a higher density and create walkable communities. Investments should be made to improve pedestrian and cyclist infrastructure as well as public transit. Automated vehicles will not replace public transit, but rather be a supplement to it. These investments should begin as soon as possible. Even though CAVs are likely decades away from widespread use, cities need to be ready to handle the challenges that CAVs will bring. Cities have to plan for how CAVs will alter urban living preferences and travel patterns, as well as how CAVs require significant transportation infrastructure investments. If not, cities more suffer more urban flight, resulting in underutilized and unattractive urban centers.

States and local governments should look to disincentivize excessive travel, single occupant travel, or zero occupant travel where the CAV is traveling without any passengers. One example of a disincentive would be a mileage-based user fee (MBUF). An MBUF is a fee imposed on vehicle travel, based upon the number of miles traveled. The implementation of this kind of system should result in the elimination of a gas tax. While this system has not been officially implemented in any U.S. state, it has been the subject of a number of pilot programs. Taxing miles traveled will disincentivize individuals from moving into the suburbs and making longer commutes. Disincentivizing suburban development will save fuel from excessive travel, decrease pollution associated with vehicle travel, limit the use of and wearing down of public infrastructure, and preserve land that would otherwise be developed for suburban housing.

Conclusion

Automated vehicles are no longer the stuff of science fiction novels and films. CAV testing has demonstrated that the vehicles could become commercially available as soon as 2020-2030, at a steep price. By 2060, these vehicles are likely to approach full market saturation. Just as the automobile aided in increasing suburbanization in the 20th century, so too can the CAV. For that reason, planning professionals and policy makers must begin to proactively plan for the impacts of autonomous vehicles. Failing to direct smart growth will result in more unsustainable suburban development. Without government intervention or proper city planning, CAVs could lead to more urbanization or more suburbanization. As is the nature of many brand-new technologies, the full consequences, both intended and unintended, of connected and automated vehicles cannot be known. Federal, state, and local agencies must advance scholarly research to determine future generational trends and proactive planning.

References

Anderson, J., Kalra, N., Stanley, K., Sorensen, P., Samaras, S., & Oluwatola, O. (2014). *Autonomous vehicle technology: A guide for policymakers*. Santa Monica, CA: RAND Corporation.

Anderson, M., & Larco, N. (2017). *Land use and transportation policies*. Davis, CA: Institute of Transportation Studies, University of California Davis.

Barnes, P., Swan, B. *High Definition Mapping and Data Collection*. Institute for Public Administration. University of Delaware. December, 2018.

Barnes, P. *Privacy in Connected and Automated Vehicles*. Institute for Public Administration. University of Delaware. May, 2018.

Barnes, P., Swan, B. Urban Planning for Connected and Automated Vehicles. Institute for Public Administration. University of Delaware. July, 2018.

Berger, A., Laberteaux, K., Hamza, K., & Brown, C. *Driven To Expansion - Suburbanization, Decentralization, And Automated Driving*. MIT Norman B. Leventhal Center for Advanced Urbanism.

Clements, L., & Kockelman, K. (2017). Economic effects of automated vehicles. *Transportation Research Record: Journal of the Transportation Research Board*, 2602, 106- 114.

Clewlow, R., Mishra, G., Jenn, A., & Laberteaux, K. (2017, November 30). Urban Travel and Residential Choices Across Generations: Results from a North American Survey. Retrieved from https://trid.trb.org/view/1495886

Dennis, E.P., Spulber, A., Brugeman, V.S., Kuntzsch, R., & Neuner, R. (2017). *Planning for connected and automated vehicles*. Ann Arbor, MI: Center for Automotive Research.

Desouza, K., Swindell, D., Smith, K. L., Sutherland, A., Fedorschak, K., & Coronel. (2015). *Local government 2035: Strategic trends and implications of new technologies* (Issues in Technology Innovation). Washington, DC: Brookings.

Dimock, M. (2018, March 01). Where Millennials end and post-Millennials begin. Retrieved from http://www.pewresearch.org/fact-tank/2018/03/01/defining-generations-where-millennials-end-and-post-millennials-begin/

Fagnant, D., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers, and policy recommendations for capitalizing on self- driven vehicles. *Transportation Research Part A: Policy and Practice*, 77, 167-181.

Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies*, 40, 1–13.

Fox, S. (2016). Planning for density in a driverless world. *Northeastern University Law Journal, Forthcoming*.

Golson, J. (2016, August 16). Ford will build an autonomous car without a steering wheel or pedals by 2021. Retrieved from https://www.theverge.com/2016/8/16/12504300/ford-autonomous-car-ride-sharing-2021

Hawkins, A. J. (2018, January 12). GM will make an autonomous car without steering wheel or pedals by 2019. Retrieved from https://www.theverge.com/2018/1/12/16880978/gm-autonomous-car-2019-detroit-auto-show-2018

Heinrichs, D. (2016). Autonomous driving and urban land use. In M. Maurer, J. C. Gerdes, B. Lenz, & H. Winner (Eds.), *Autonomous Driving* (pp. 213–231). Berlin: Springer.

Huddleston, T. H. (2018, June 27). Move over Telsa, this self-driving Volvo will let you sleep during your highway commute. Retrieved from https://www.cnbc.com/2018/06/26/volvo-self-driving-car-sleep-watch-movie-on-commute-by-2021.html

Kockelman, K., Boyles, S., Stone, P., Fagnant, D., Rahul, P., Levin, M. W., ... Li, J. (2017). *An assessment of autonomous vehicles: Traffic impacts and infrastructure needs* (No. 0- 6847–1). Austin, TX: Center for Transportation Research, University of Texas.

Kopecky, K., & Suen, R. (2010). A QUANTITATIVE ANALYSIS OF SUBURBANIZATION AND THE DIFFUSION OF THE AUTOMOBILE. *International Economic Review, 51*(4), 1003-1037. Retrieved from http://www.jstor.org/stable/40929500

Litman, T. (2018). *Autonomous vehicle implementation predictions: Implications for transport planning*. Victoria, BC: Victoria Transport Policy Institute.

McKinsey & Company. Automotive revolution – perspective towards 2030 How the convergence of disruptive technology-driven trends could transform the auto industry. (2016, January). Retrieved from https://www.mckinsey.com/~/media/mckinsey/industries/high tech/our insights/disruptive trends that will transform the auto industry/auto 2030 report jan 2016.ashx

Moos, M. (2018). The millennial city: Trends, implications, and prospects for urban planning and policy. London: Routledge, Taylor & Francis Group.

Morgan Stanley. (2013). *Autonomous cars: Self- driving the new auto industry paradigm*. New York, NY: Morgan Stanley.

National Highway Traffic Safety Administration. (2018). *Automated Vehicles for Safety*. Retrieved from https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

National Highway Traffic Safety Administration. (2016). *Federal automated vehicles policy: Accelerating the next revolution in roadway safety*. Washington, DC: National Highway Traffic Safety Administration.

Nourinejad, M., Bahrami, S., & Roorda, M. J. (2018). Designing parking facilities for autonomous vehicles. *Transportation Research Part B: Methodological*, *109*, 110– 127. Saiz, A., & Salazar, A. (2017). *Real trends: The future of real estate in the United States*. Cambridge, MA: Center for Real Estate, Massachusetts Institute of Technology.

akaria, N., & Stehfest, N. (2013). *Millennials & mobility: Understanding the millennial mindset and new opportunities for transit providers*. Washington, DC: Transportation Research Board.

Shaheen, S., & Cohen, A. (2013). *Innovative mobility carsharing outlook: Carsharing market overview, analysis, and trends*. Berkeley, CA: Transportation Sustainability Research Center.

Shoup, D. (2011). *The high cost of free parking*. Chicago, IL: Routledge.

Sivak, M., & Schoettle, B. (2015). *Road safety with self-driving vehicles: General limitations and road sharing with conventional vehicles (*No. UMTRI-2015-2). Ann Arbor, MI: The Unversity of Michigan, Transportation Research Institute.

Skinner, R., & Bidwell, N. (2016). *Making better places: Autonomous vehicles and future opportunities*. London, UK: WSP | Parsons Brinckerhoff.