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Implications of Market Penetration of Electric and Autonomous Vehicles for Florida State Transportation Revenue

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Electric vehicle (EV) and autonomous vehicle (AV) technologies represent what seems to be beneficial, but potentially disruptive, shift in the way people and goods are transported. Wider use of EVs offers an opportunity to reduce harmful emissions, while widespread adoption of AVs has the potential to significantly improve vehicle safety, reduce congestion and impact vehicle ownership and travel habits. Since EVs do not consume petroleum fuels, they do not pay gas taxes that are used to fund transportation infrastructure. With EVs currently representing a small share of vehicle fleet, gas tax losses are minor, but as the market penetration increases, legislative bodies will encounter continuous pressure to address growing shortfall in transportation infrastructure funding. A study by the Florida Department of Transportation (FDOT) projected that the combined cumulative effect of increased EV and AV market penetration on total transportation revenue losses in Florida will reach $18.3 billion by 2048, including $5.3 billion loss from federal taxes, $9.7 billion loss from state taxes and $3.3 billion loss from local transportation taxes. Addressing these shortfalls may require to adjust motor fuel excise taxes to better reflect growing fuel economy, impose EV fees and taxes, implement mileage-based transportation fees or other funding models.

Keywords: *electric vehicle, autonomous vehicle, electric vehicle miles travelled, fuel efficiency, revenue loss*

Introduction

Widespread adoption of electric vehicles (EV) and autonomous vehicles (AV) are expected to have the most profound impact on transportation planning and investment since the invention of the automobile. Vehicle manufacturers and transportation providers around the world are investing substantial resources developing and refining these technologies. Significant changes can be expected in how we travel, what mode and vehicle type we use, how our goods are transported and how our living, working, and travel patterns are determined.

There is high uncertainty regarding how electric and autonomous vehicle technologies will develop, when their acceptance in the marketplace will occur, what additional investments may be needed to facilitate their adoption, what

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potential savings may be realized, and what impacts they may have on traditional transportation infrastructure funding sources. As such, there exists significant degree of risk with respect to what actions state governments should take to prepare for the ensuing implications on infrastructure needs and revenue funding flows. Such risks include the potential for underinvesting in required transportation infrastructure, resulting from underestimating the development of EV and AV technologies, or directing limited financial resources in areas that do not address future transportation needs.

To effectively plan for the influx of electric and autonomous vehicles and to create a transportation system for the future, transportation officials at the national and state levels must gauge the market penetration rate of these technologies and monitor how they will contribute to fleet fuel efficiency, vehicle miles travelled (VMT) and changes in travel habits, as well as forecast the impact of these new technologies on traditional infrastructure funding mechanisms.

The current paper summarizes the result of comprehensive market penetration analysis of EV and AV technologies in Florida and reports on projected impacts of these technologies on VMT and state transportation revenue collection. The long-range (30-year) forecast presented in this analysis was developed to assist Florida Department of Transportation (FDOT) in addressing future transportation infrastructure needs and revenue requirements as EV and AV market penetration rates increase.

Market Penetration Analysis and Literature Review

Electric Vehicles

In 2018, global electric vehicle, including EVs and plug-in hybrid electric vehicles (PHEV), sales exceeded 2 million units, with the United States being the third largest EV market in the world, following Europe and China (Loveday 2019). From 2011 through 2018, the global EV market averaged an annual growth rate of about 50%. Dramatic improvements in EV performance, safety, and reliability contributed to the increased adoption of these vehicles. In 2018, about 361,000 EVs were sold in the United States, representing 2% of national light-duty vehicle sales, with nearly half of EV sales taking place in California. In June 2019, U.S. EV sales reached approximately 2.5% of all light-duty vehicle sales (Loveday 2019). While the electric vehicle market share remains low, its compound annual growth rate ranged between 20% and 30% over the past seven years. This growth may slow, at least temporarily, as federal purchase incentives (up to $7,500 per vehicle) are phased out for manufacturers who exceed 200,000 EV sales. In 2018, Tesla and General Motors reached this threshold.

The U.S. EV stock continues to grow with vehicle sales but remains relatively low. Despite national sales growth, the current EV/PHEV stock is estimated at slightly over 1 million vehicles, or approximately 0.37% of the total light-duty vehicle stock (AAM 2019).

The major factors influencing EV market penetration relate to government policies, vehicle costs, consumer attitude and awareness, availability of EV models, and fueling infrastructure. Major government policies that affect national EV sales include the California zero-emission vehicle (ZEV) program, the California Global Warming Solutions Act of 2006 that requires sharp reductions in greenhouse gas (GHG) emissions and a federal tax credit that provides up to $7,500 for purchasing EV/PHEVs, as well as CO_2 credits provided under the Environmental Protection Agency (EPA) Corporate Average Fuel Efficiency (CAFE) standards. Some states have also implemented various incentive and policy programs aimed at accelerating EV adoption, including grants, tax incentives, loans and leases, rebates, and exemptions. Incentives play a vital role in developing the EV market, particularly those that provide direct financial benefits to vehicle owners.

From a technological standpoint, the primary driver of EV/PHEV costs and sales is the battery cost. Between 2010 and 2018, the cost of automotive batteries (measured per kilowatt hour) decreased by 80%, from over $1,000/kilowatt hour (kWh) to approximately $200/kWh, and is projected to continue declining, potentially falling below $100/kWh by 2030 (Lutsey and Nicholas 2019). Industry experts believe that electric vehicles will be able to reach true price parity with traditional gasoline/diesel-powered vehicles when battery costs fall below $100/ kWh, which is conservatively projected to occur between 2025 and 2030. Battery management systems and technology improvements are extending battery durability. Lithium-ion technology is projected to remain the primary technology for automotive batteries in the near future and will see further improvements in energy density and efficiency, making batteries smaller and lighter.

EV Market Projections

EV market penetration projections vary significantly from source to source. The Energy Information Administration (EIA) forecasts that sales of EV/PHEVs will exceed 1.1 million vehicles per year, accounting for 7% of all light-duty vehicle sales in 2025. EV/PHEV sales are also projected to reach 14% of annual vehicle sales in 2050 (EIA 2018). The National Renewable Energy Laboratory (NREL) forecasts that EVs will account for 20% of all light-duty vehicle sales in the United States in 2030. More aggressive forecasts place the share of EV sales at 35% of new light-duty vehicle sales in 2040, and up to 60% of all light-duty vehicle sales in 2050.

Overall, the reviewed EV sales forecasts imply short-to-medium-term (10–15 years) annual growth rates ranging from 20.6% to 25.1%, and long-term (20+ years) growth rates ranging from 7.5% to 16.0%. The projections regarding the stock of EVs found in the literature range from 7 million vehicles in 2025 to 15 million in 2030, and 41 million vehicles in 2040. Even the most aggressive forecasts, however, indicate that the electric vehicle fleet is not expected to exceed 15% of the overall U.S. vehicle stock in 2040.

Autonomous Vehicles

Although AV technology is still in the testing phase, there is a growing body of research focused on its impact on travel demand as measured by vehicle miles traveled. The Society of Automotive Engineers (SAE) International established functional definitions of AV capabilities, ranging from Level 0 to Level 5, where higher level describes wider range of functions that the vehicle can perform without human involvement. SAE levels of automation are described in Table 1.

Table 1. *Levels of Driving Automation*

<table>
<tr><th>SAE Level</th><th>Name</th><th colspan="2">Definition</th></tr>
<tr><td>0</td><td>No Automation</td><td colspan="2">The full-time performance by the human driver of all aspects of the dynamic driving task, even when "enhanced by warning or intervention systems"</td></tr>
<tr><td>1</td><td>Drive Assistance</td><td>The driving mode-specific execution by a driver assistance system of "either steering or acceleration/deceleration"</td><td rowspan="2">using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task</td></tr>
<tr><td>2</td><td>Partial Automation</td><td>The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration</td></tr>
<tr><td>3</td><td>Conditional Automation</td><td rowspan="3">The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task</td><td>with the expectation that the human driver will respond appropriately to a request to intervene</td></tr>
<tr><td>4</td><td>High Automation</td><td>even if a human driver does not respond appropriately to a request to intervene</td></tr>
<tr><td>5</td><td>Full Automation</td><td>under all roadway and environmental conditions that can be managed by a human driver</td></tr>
</table>

Source: Society of Automotive Engineers (SAE 2018).

AV Market Projections

The reviewed literature indicates that autonomous vehicles will likely enter the private vehicle market in a top-down pattern, first arriving in the larger and luxury car segments and only after that becoming available in the medium, small, and compact or pick-up vehicle categories. Level-4 functionality will initially become available in testing environments in 2020–2025 and will diffuse through vehicles of different categories by the early to mid-2030s. In the early 2030s, the smaller and lower-priced vehicle categories will include Level-4 capabilities. In the early 2030s, the Level-5 technology will debut in the larger and luxury segments. By the 2030–2040 timeframe, these features will be introduced into the medium to compact vehicle market segments. Given the current technological developments and regulations, it can be expected that by 2035, Level 4-5 AV technology will encompass 35% of the private vehicle market share and anywhere from 11% to 14% of the private vehicle fleet.

One way AVs can affect vehicle travel demand is through supplying shared mobility services to the currently underserved, including youth, the elderly, and those with driving-prohibitive medical conditions. The shared mobility concept, which enables users to gain short-term access to transportation on an as-needed basis, is gaining popularity, especially with the younger generation of drivers. Recent developments in vehicle automation create additional opportunities for a wider adoption of the shared vehicle model. If fully autonomous vehicles become a reality, they can be used more efficiently to provide mobility to multiple users.

The literature review indicated that the estimated impact of new travel demand from the underserved population can result in a 2% to 14% increase in VMT (Harper et al. 2016).

Florida Market Penetration Analysis – EVs

The market acceptance of EVs depends on many factors, including demographics and socioeconomics, geography and climate, gasoline and electricity pricing, charging infrastructure availability, government incentives, as well as consumer perception, personality, and social influences.

During the past 20 years, Florida's population grew almost twice as fast as the overall population of the United States and that trend is expected to continue. Additionally, Florida's population density is significantly higher than the national average and future growth in Florida is expected to concentrate mainly within urban areas. Population growth and density are expected to have a positive effect on the adoption of plug-in electric vehicles (PEVs) in the state.

In addition to demographic, socioeconomic, and population factors, geography and climate considerations could affect EV growth, though to a lesser degree. Climate and regional temperature variation can affect the performance, efficiency, and range of EVs, which depends on battery capacity and vehicle efficiency. With its subtropical climate, Florida experiences the highest average annual temperature compared to other states. Due to its climate and temperature patterns, Florida yields some of the most optimal energy efficiency and EV range in the country, making it a favorable market for electric vehicle adoption.

Battery electric vehicles make up a greater share of electric vehicle sales in Florida than in most other states. As of June 2018, Florida battery electric vehicle sales accounted for 61.3% of total plug-in electric vehicle (PEV) sales, which is higher than the national average share of 51.3%. During the period of 2013–2018, Florida's PEV sales grew at an average annual rate of 20% per year, faster than other non-zero-emission vehicle states, which grew at an average annual rate of 16.5%. In 2018, approximately 42,962 plug-in electric vehicles were registered in the state, including 17,807 plug-in hybrid-electric and 25,155 battery electric vehicles (AAM 2019).

EV infrastructure availability is often cited as an important factor in accelerating PEV adoption. Florida's network of electric vehicle charging infrastructure continues to grow rapidly. As of August 2019, there were more than 3,300 charging outlets, including 1,139 Level 2 charging locations (with 2,640 ports) and 163 fast charging stations (with 630 ports) (AFDC 2019). While Florida has roughly 3.6% of the national stock of electric vehicles, its Level 2 and fast chargers account for approximately 5.0% of the national EV charging infrastructure. The state is expected to add an additional 530 public EV charging stations through 2022 as a result of the Duke Energy Park and Plug Program.

At present, Florida lacks any rebate, grant, or tax incentive program to accelerate PEV adoption. However, in recent years state electric utilities began offering rebate and incentive programs incentivizing PEV ownership and lowering the installation cost of charging infrastructure.

Overall, there are a number of positive factors that contribute to Florida's increasing growth in PEV sales, including favorable climate, a greater preference for automobiles over light trucks than most other states, relatively low electricity costs, and a relatively high population density to support the developing vehicle charging infrastructure. Factors that may inhibit PEV growth, or delay growth until PEV costs decline, include lower than national average household incomes, a large sector of lower wage service jobs, and relatively few state and local incentives, including non-participation in the Zero-Emission Vehicle Program.

Florida Market Penetration Analysis – AVs

Various studies project that by 2030, AVs will make up around 18.5% of the U.S. vehicle fleet. The share will gradually increase to 25.4% in 2035 and 30.0% by 2040. The reviewed literature suggests that by 2045, approximately 43.0% of the U.S. fleet may consist of AVs, and that by 2050 AVs can make up almost half of the nation's vehicle fleet (Bansal and Kockelman 2017, Bierstedt et al. 2014, Trommer et al. 2018).

Several state-specific factors may impact Florida's AV adoption rates to diverge from these national trends, including population age, income level, education level, and urban density. Several studies find that AV acceptance is positively associated with a younger population (Haboucha et al. 2017, Nielsen and Haustein 2018, Schoettle and Sivak 2014), higher income levels (Howard and Dai 2014, Kyriakidis et al. 2015, Zmud 2016), higher levels of education (Haboucha et al. 2017, Nielsen and Haustein 2018), and urban environments (Nielsen and Haustein 2018, Bansal and Kockelman 2017, Nordhoff et al. 2018). According to the U.S. Census Bureau, the median household income measured in Florida in 2012–2016 was $48,900 in 2016 dollars (US Census 2018), relatively lower than the national median of $55,322. On the other hand, the distribution by income levels in Florida is similar to the rest of the country. Assuming some similar accessibility to AVs across different income groups, it will be difficult to discern a clear relationship between income levels and AV VMT.

Florida's population currently includes a larger percentage of persons 65 and over compared to the rest of the United States. According to the U.S. Census, as of

July 2017, 20.1% of Florida's population is 65 and over, compared to 15.6% nationally. The Bureau of Economic and Business Research (BEBR) projects that by 2040, this group will represent about a quarter of the state's population. Based on the existing demographic characteristics and BEBR projections, and assuming the association between AV acceptance and age remains constant, it is expected that these population forecasts will result in a somewhat more moderate AV market acceptance in Florida compared to national trends.

New mobility options exist in population-dense, urban areas, which provide the opportunity for economies of scale. Nine of the large and population-dense metropolitan areas in the United States contain 70% of Uber and Lyft trips (Schaller 2018). Florida is more densely populated than the rest of the country, with a population density of 350 persons per square mile compared to a national average of 87 persons per square mile. Florida is also the eighth most population-dense state. Combined with the population growth that is faster than the national average, this makes urban Florida among the fastest growing areas in the nation, increasing the likelihood of options such as shared mobility services provided by transportation network companies (TNCs).

TNCs may lead individual adoption by providing mobility services in the form of shared autonomous vehicles (SAVs) or pooled autonomous vehicles (PAVs), which are SAVs that may pick up other passengers en route. Interest of TNCs in implementing practical AV solutions combined with reduced individual willingness to own vehicles, suggests that TNCs may be primary early adopters of AV technologies.

Methodology

The analysis presented in the current paper is based on forecasting total state VMT and VMT driven on electric propulsion (eVMT) during the period from 2018 through 2048. This involves estimating market penetration of EVs in Florida fleet during the 30-year projection period based on the national trends and Florida-specific factors that affect the adoption of electric and autonomous vehicle technologies.

Florida VMT estimate is produced by adjusting 2017 FHWA 30-year national VMT forecast for light-duty (LD) vehicles, single-unit trucks (SUT), transit buses and combination trucks (CT) to Florida-specific socio-economic factors that are assumed to affect VMT generation, including population growth, growth in real GDP, growth in disposable income per capita and gasoline prices. The forecasting approach assumes that Florida VMT growth will follow the general pattern of the U.S. VMT, growing faster during the first 20-year period and slowing down during the last 10 years of the 30-year projection period.

Electric VMT projections are obtained by combining forecasted number of electric vehicles in three vehicle subcategory (passenger vehicles, single-unit trucks and buses, combination trucks) with projected VMT per electric vehicle. The per-vehicle eVMT estimates are based on the assumptions regarding the shares of battery-electric vehicles (BEV) and plug-in electric vehicles (PHEV) in

Florida EV fleet, as well as the estimated electric range of these vehicles during the 30-year forecast period. Autonomous vehicles are not expected to account for a significant portion of VMT until at least 2035.

All forecasts are generated using modeling techniques consistent with the ones currently employed by the state of Florida (with minor adjustments to address the goals of the assessment) and are based on publicly available data and research results from reputable sources, such as FHWA, U.S. DOT, U.S. Department of Energy (DOE), National Renewable Energy Laboratory (NREL), EPA, FDOT, etc.

Florida Office of Economic and Demographic Research Revenue Estimating Conference (REC) produces forecasting for economic, demographic, and revenue impacts to inform the development of planning and budgeting for state resources. The current analysis incorporates REC assumptions for the period of state fiscal year 2018–2019 through 2027–2028 for the purposes of consistency with state forecasts and demographic assumptions, with the exception of REC projections for current and future miles per gallon (MPG) levels. Projections beyond 2028 utilize the same approach employed by REC, with minor adjustments.

Estimating fleet fuel efficiency is based on modelled state fleet mix and reflects the smaller share of combination trucks in Florida than is found nationally - approximately one-third less compared to national share. While the percentage change in combination truck VMT share is small (1.8%), the effect on revenue impact is considered to be a material factor since combination trucks on average consume four times more fuel per VMT compared to LD vehicles.

Results

Under baseline VMT growth forecast, total Florida VMT is projected to reach 335.9 billion annually by the year 2048. Under high VMT growth scenario, VMT is forecasted to be as high as 379.9 billion. The low growth scenario results in VMT projection of 295.1 billion per year in 2048.

The projection of the number of EVs in Florida, in comparison with the national EV market, employs a weighted index approach, similar to the one that has been used for baseline VMT projections in the state. Key macroeconomic parameters that are used as predictors of EV market development in Florida include growth in disposable income per capita, gasoline prices, availability of government EV rebates/incentives, residential electricity rates, and prices of photovoltaic panels in Florida in comparison to national averages.

eVMT Forecasting

Total electric VMT in Florida is estimated by combining the projections of the number of EVs in Florida with the forecasted average annual eVMT per electric vehicle. Separate eVMT projections were developed for each subcategory of vehicles in the fleet (LD, SUT and buses, CT). Total eVMT in Florida is projected to reach 47.5 billion by 2048, accounting for about 14.0% of the overall VMT in the state.

Table 2 presents the summary of the forecasted eVMT in Florida during the period from 2020 through 2048.

Table 2. *Projected eVMT Forecast for Florida (2020–2048)*

eVMT Forecast (Millions)				
Year	**Total**	**Light-duty**	**SUT/B**	**Combination Trucks**
2020	**559.6**	559	0.5	0.0
2025	**2,893**	2,873	19.2	0.5
2030	**6,629**	6,564	48.9	16.7
2035	**11,669**	11,451	160.0	57.6
2040	**20,039**	19,358	482.2	198.7
2045	**34,573**	32,372	1,515.2	686.0
2048	**47,502**	43,010	3,049.7	1,442.7

AV Impact on VMT and Fuel Economy

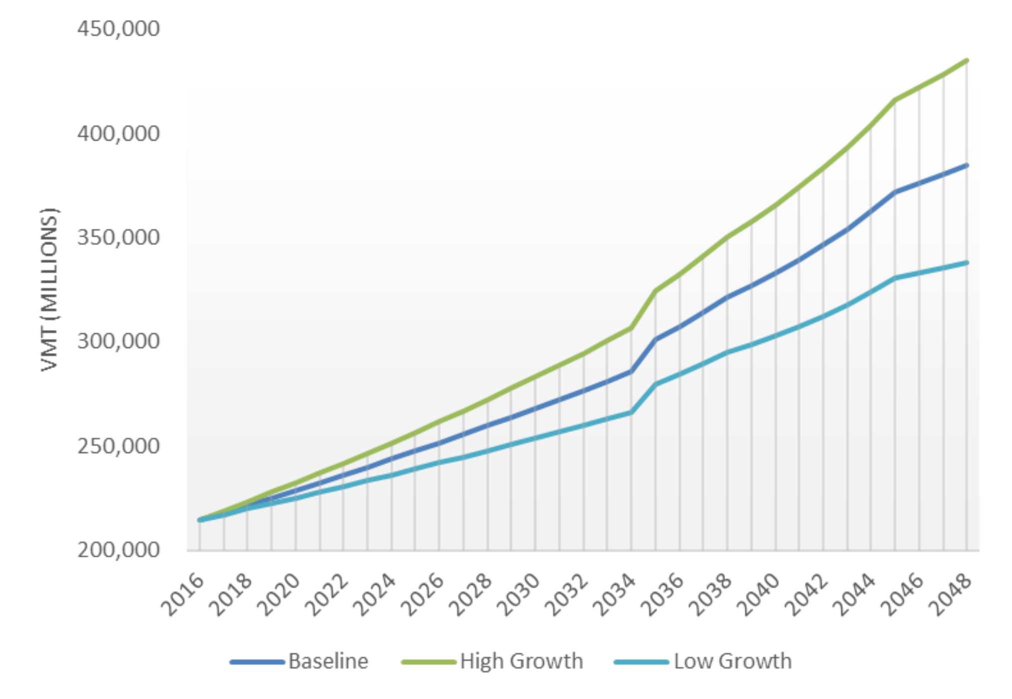
This analysis projects a rather modest penetration rate of AV technologies. AVs are not expected to account for a significant portion of VMT until at least 2035. By 2035, VMT from AVs is projected to account for 3.8% of total Florida VMT, increasing to 7.29% of total Florida VMT by 2040 and 14.56% of total Florida VMT by 2048. The analysis assumes that all AV VMT in Florida will be eVMT from light-duty vehicles.

Autonomous vehicles are expected to drive more VMT per vehicle compared to other vehicles due to reduced cost of travel offered by AV technologies and likely use of AVs for ride sharing applications. Autonomous driving is projected to increase the average eVMT per electric vehicle by 35% starting from 2035.

Starting from 2029, AVs are projected to generate noticeable impact to VMT generation in Florida. In 2035, implementation of AV technologies is projected to add 0.6 percentage points to annual growth rate of VMT in Florida. By 2040, AV technologies will be responsible for adding 0.8 percentage points to annual VMT growth of 1.1%, accounting for 42.1% of the overall VMT growth in that year.

Total VMT from AVs in Florida is projected to reach 11 billion VMT by 2035, 22.6 billion VMT by 2040, 45.7 billion VMT by 2045 and almost 49.0 billion VMT by 2048. Figure 1 presents forecasted Florida VMT under different growth scenarios, accounting for the impact of AV technologies.

Figure 1. *Projected Florida VMT with AV Impact*



Projected Growth in EVs

The current analysis projects that the number of EVs will increase in Florida from 43,000 units in 2018 to 278,275 units in 2025 and over 3.6 million by 2048, with the majority of those vehicles to be concentrated in the higher density metropolitan areas. Light-duty vehicles are expected to account for the vast majority of EVs in Florida through the entire projection period, and will account for 93.0% of the total Florida EV fleet in 2048. The current approach also forecasts that by 2048, 18.0% of single-unit trucks and 10.0% of semi-trucks in Florida will be battery-electric.

Overview of Florida Transportation Revenue Sources

In 2017, $7.8 billion in transportation taxes and fees were collected in Florida. This consisted of $2.6 billion in federal fuel, heavy truck, and aviation taxes, $1.4 billion in local option fuel taxes and state fuel taxes that are dedicated for local use, and $3.9 billion in state fuel taxes, vehicle-related fees, and impact fees. Approximately one-half of these revenues are collected for state purposes, one-third - for federal, and one-sixth by and for local governments. Federal highway funds are appropriated to state highway departments and transit funds to state and local entities (FDOT 2017).

Taxes based on motor fuel consumption accounted for 72% of total collections. As of January 1, 2019, the combined rate for federal, state and local motor fuel taxes in Florida totaled 56.7 cents per gallon on diesel and ranged from 50.3 cents to 56.3 cents per gallon on gasoline based on the level of local option gasoline tax levies in individual counties. Statewide, gasoline taxes averaged 54.0 cents per gallon. These rates include the January 1, 2019, 0.6 cents per gallon state motor fuel taxes increase as a result of annual consumer price index (CPI) adjustment provisions.

In 2017, federal, state and local transportation taxes and fees generated approximately 3.6 cents per mile of vehicle travel in Florida: 1.2 cents per mile from federal taxes, 1.6 cents per mile from state taxes and 0.6 cents per mile from local taxes. Of this total, the motor fuel tax collections accounted for approximately 2.6 cents per mile: one cent each from federal and state taxes and 0.6 cents from local taxes (FDOT 2017).

State Revenue Impact from EV and AV

In general, the growth in eVMT is expected to reduce demand for gasoline and diesel fuel and, in turn, negatively affect revenue generation. Lost motor fuel tax revenues resulting from the increasing use of battery electric vehicles and plug-in hybrid electric vehicles are expected to have a significant impact on transportation revenues over time, assuming the present transportation tax structures in Florida remain unchanged. This impact will remain relatively small in comparison to total transportation revenue collections until the time when EV fleet reaches significant numbers and approaches parity with internal combustion engine (ICE) vehicles.

A number of factors tend to lessen the initial impact of EV/PHEV and eVMT on transportation revenue losses, including average miles driven, utility factor and average fuel economy of vehicles replaced by EVs.

Average Miles Driven

A report from the California Air Resources Board indicated that, while owners of PHEVs drove on average a similar number of miles when compared to traditional ICE vehicle users, battery electric vehicles were driven approximately 80% of ICE annual vehicle miles (CARB 2017). This difference is likely due to current range and recharging limitations with EVs that should lessen over time as battery capacities increase and more recharging options become available.

Utility Factor

An analysis of PHEVs purchased in the U.S. in 2016 indicates an average utility factor (the percentage of eVMT to total miles driven) of 0.52, meaning that 48% of miles driven were powered by an internal combustion engine and consuming motor fuel (EPA 2016). With a utility factor of 0.52, the effect of PHEVs on lost consumption of motor fuel per vehicle is approximately one half of the total motor fuel that would have been consumed by the ICE comparable vehicle. Utility factors are expected to increase as battery costs fall and higher capacity batteries are installed in PHEVs. Additionally, as battery-electric vehicles (EV) represent larger percentage of plug-in electric vehicle (EV and PHEV) sales, the average utility factor of the electric vehicle fleet will increase.

Age and Fuel Economy of Vehicles Replaced by EVs

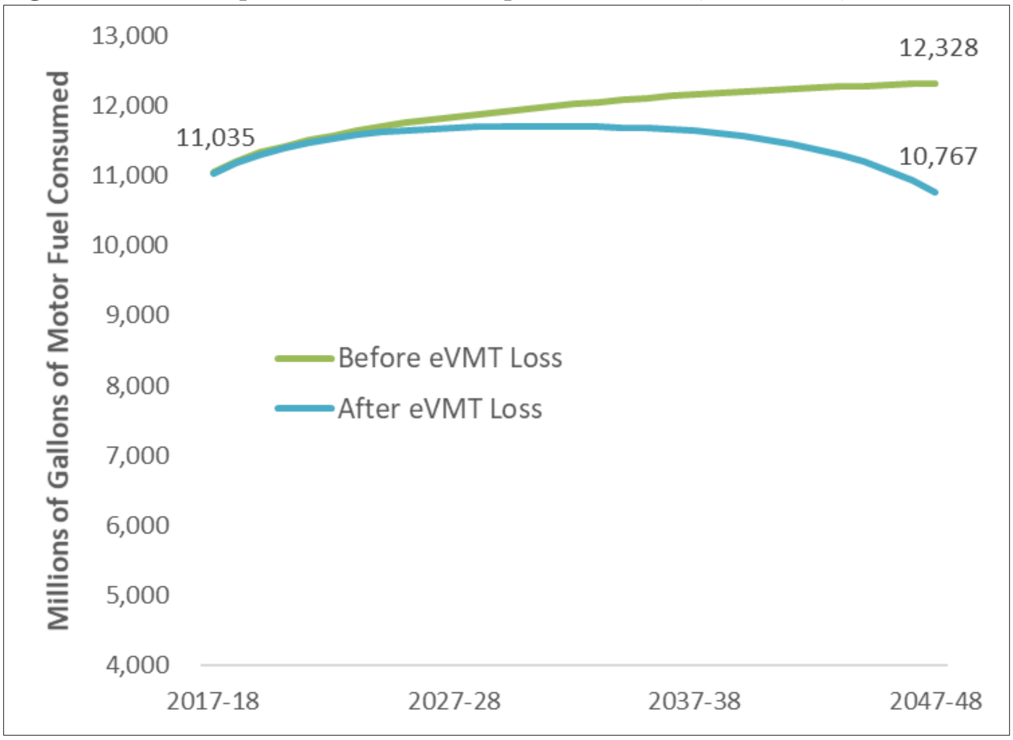
New cars and trucks are typically more fuel efficient than the average of the entire state fleet of registered vehicles, which contains a large percentage of older, less efficient vehicles. For example, new cars and trucks sold in 2017 were, on average, 19% more fuel efficient than vehicles sold ten years prior. It has been noted that, EV purchases are often offsetting more efficient vehicles compared to the average efficiency of the state's vehicle fleet, given that available EVs tend to be comparable in size to smaller, more efficient ICE vehicles. An analysis of 2017 vehicle sales suggested that EV vehicles replaced ICE vehicles that averaged 1.4 MPG, or 5.5% greater efficiency than the average MPG for all car and light truck sales in that year. This results in fewer gallons of motor fuel not consumed relative to vehicle miles traveled than is found for the statewide vehicle fleet on average, and the corresponding reduction in motor fuel taxes not levied are less than the state average per average car.

EV Impact on Motor Fuel Consumption

Improvements in conventional vehicle technology and emission regulations result in continuing improvements in vehicle fuel economy. As vehicle fleet becomes more efficient, it consumes less fuel resulting in less fuel tax revenue for the state. The effect of fleet fuel efficiency improvements is moderated by the growth in the number of vehicles and increases in VMT. Depending on the magnitude of the effects of VMT, size of the fleet and average vehicle efficiency, the resulting fuel consumption can either decrease or increase. The increase of the number of battery-electric vehicles in the fleet can result in the increase in the average fuel economy of the entire fleet and cause reductions in the consumption of motor fuel.

Figure 2 demonstrates the impact of EVs on projected fuel consumption in Florida over the 30-year period. The projection shows, that without EVs in the fleet, motor fuel consumption in Florida is projected to continue growing throughout the entire 30-year projection period (due to the effects of VMT and fleet size), but at a decreasing rate (due to the effects of fuel efficiency improvements). EVs cause a faster decline in the fuel consumption growth rate. Starting from 2033–2034, the use of EVs is projected to result in a consistent reduction in the amount of motor fuel consumed annually in the state.

Figure 2. *eVMT Impact on Fuel Consumption Forecast (2018–2048)*



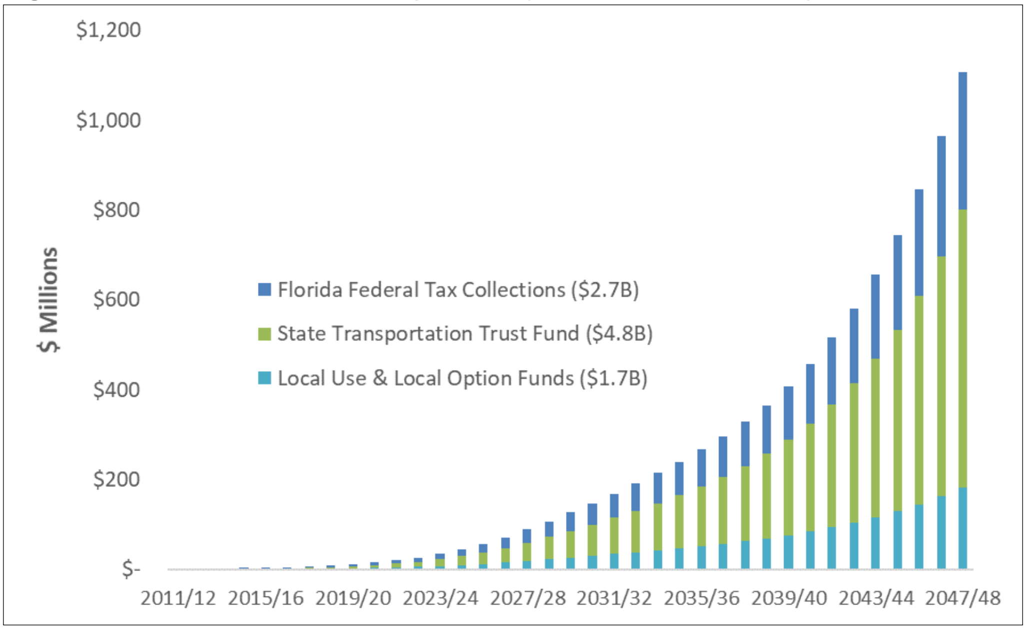
Average fuel economy of the fleet can be affected by multiple factors, including CAFE regulations, improvements in propulsion technology and vehicle materials, use of alternative fuels and other factors. Even with no EVs, Florida fleet fuel efficiency is projected to increase by almost 36.0% during 30-year forecast period, from 19.98 MPG in 2018 to 27.13 MPG in 2048. The use of EVs, that are projected to enter the fleet in large numbers after 2030, will accelerate average fleet fuel efficiency growth. Adoption of EVs is forecasted to add 1.01 MPG (an increase of 4.1% over base fuel efficiency) to the average fuel efficiency of the Florida fleet by 2037 and 3.93 MPG (an increase of 14.5% over base fuel efficiency) to the average fuel efficiency of the fleet by 2048.

Projected Revenue Loss Attributed to EV

In 2018, Florida's transportation tax revenue losses due to reduced motor fuel consumption from EV use were estimated at $17.5 million per year, including $6.4 million in Florida federal tax, $7.0 million in state transportation tax and $4.2 million in local use transportation tax collections. While tax revenue losses have been small to date, the loss rate from EV use is projected to increase over time, rising on a percentage loss basis from 0.2% of fuel tax revenues in FY 2019–2020 to 1.7% by the end of FY 2029–2030. Annual revenue losses are projected to increase from $9.5 million in FY 2019–2020 to $121 million by FY 2029–2030. Cumulative tax revenue losses in Florida through FY 2029–2030 are projected to total over $583 million, including $194 million federal taxes, $263 million state taxes and $127 million in local use taxes. The state share of total losses increases from 41.4% in FY 2019–2020 to 46.6% in FY 2029–2030 as state fuel taxes are annually adjusted to CPI while federal and local taxes are not.

An approximate nine-fold increase in the percentage share of motor fuel tax revenue lost from plug-in vehicle use is projected to occur from 2028–2029 through 2047–2048. By 2048, the percentage share is estimated to increase to nearly 13% loss in revenues, totaling $1.2 billion annually, with $651 million per year, or 56%, of the total losses coming from Florida state fuel taxes. Figure 3 demonstrates projected fuel tax revenue loss for the state of Florida through 2048.

Figure 3. *Lost Fuel Tax Revenue from Plug-in Vehicle Use through 2048*



AV Impact on VMT

Vehicle automation is not expected to have a significant effect on VMT generation in Florida in the next decade. While many manufacturers are actively working on implementing AV technologies, significant technological and regulatory challenges remain.

The implementation of AV technologies will likely take evolutionary path. Initially, AV technologies will likely be available on high-end vehicles or as paid options. It is projected, that until 2050, less than 50% of vehicles on the road will have full automation capabilities.

Projected Revenue Losses Attributed to AV

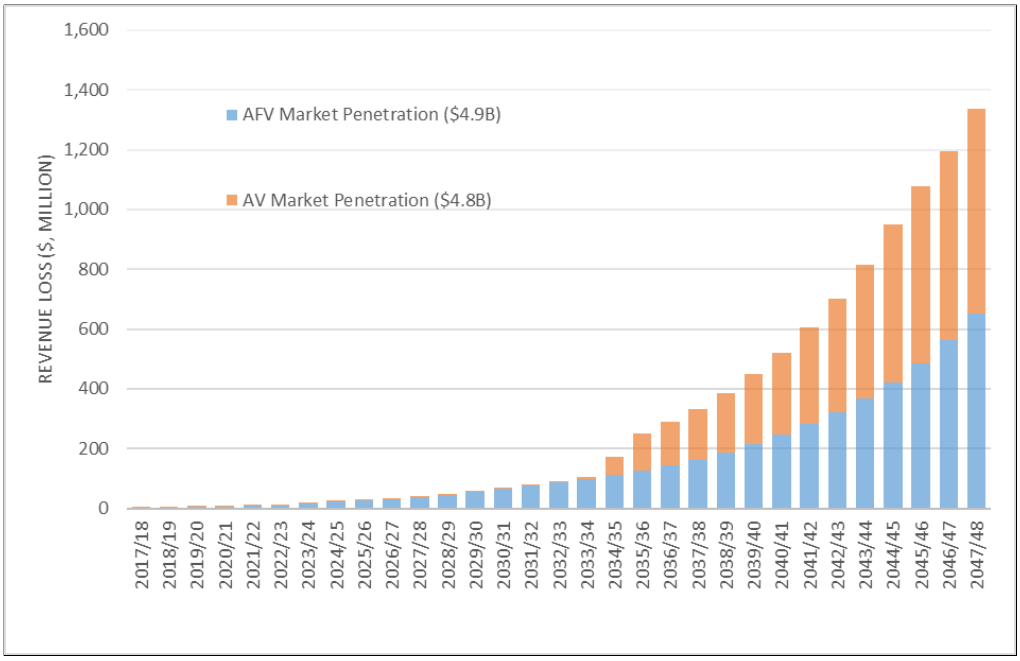
Since AV technologies are not projected to constitute a relatively noticeable share of the state fleet at least until 2030–2035, revenue loss from AV VMT is expected to be insignificant during the first half of the 30-year forecast period. In FY 2029–2030, total annual funding shortfall from AV VMT is projected to be $3.8 million, including $1.4 million loss from federal fuel taxes, $1.7 million from state fuel taxes and $0.6 million from local taxes. This annual shortfall is projected to grow to $119.5 million in FY 2034–2035, $453 million in 2039-2040 and $1.2 billion in 2047–2048. The cumulative impact of AV VMT on total Florida fuel tax collection shortfall is projected to reach $8.9 billion, in constant 2018 dollars, for the entire projection period of 2018–2048, including $2.5 billion loss from federal taxes, $4.8 billion loss from state taxes and $1.6 billion loss from local taxes.

Combined EV and AV Effect on Florida Transportation Revenue

While the impact of electric and autonomous vehicles on the overall fleet fuel efficiency are expected to be rather small during the first half of the 30-year forecast period, EVs and AVs are expected to result in a noticeable increase in the fuel efficiency of Florida fleet after 2035. By 2040, EVs are expected to add 1.39 MPG to the average fuel efficiency of the fleet while AVs are expected to add 1.83 MPG to the average fuel efficiency of Florida fleet. By 2048, EVs and AVs combined, are projected to add 8.42 MPG to the average fuel efficiency of Florida fleet (3.93 MPG from EV impact and 4.49 MPG from AV impact).

Over the period of 2018–2048, the combined cumulative impact of EV and AV market penetration on total Florida transportation revenue collection is projected to reach $18.3 billion, including $5.3 billion loss from federal transportation taxes, $9.7 billion loss from state taxes and $3.3 billion loss from local transportation taxes. Figure 4 demonstrates the combined projected effect of EV and AV technologies on Florida state transportation tax revenues.

Figure 4. *Combined Revenue Losses in State Fuel Taxes from EV and AV Market Penetration in Florida*



At the end of FY 2027–2028, lost revenues are projected to reach 1.3% of fuel-based state transportation tax collection. Rapid growth in EV and AV adoption is projected to increase state revenue losses to about 26% of the fuel-based transportation tax revenue in Florida by 2048.

These losses do not include potential reduction in capital and operating costs that AV might generate by roadway capacity improvements from cooperative driving. Recent simulation-based studies show potential capacity improvement ranging between 10% and 30% from high AV market penetration (60–100%) (Fagnant and Kockelman 2015).

Policy Considerations

Transportation infrastructure in the U.S. is funded by fuel taxes. Every gallon of diesel or gasoline sold is taxed and the proceeds from these taxes are used to build and maintain roads. Electric vehicles do not consume gasoline or diesel and, thus, do not contribute to gas taxes. Motor fuel-based taxes, which historically have served as an effective and administratively efficient surrogate for a user-fee based collection system, are becoming increasingly less effective in this role as vehicle fuel efficiencies continuously increase and as non-motor-fuel powered vehicles are adopted in greater numbers.

If the current trends in vehicle electrification and automation continue, government entities in Florida (as well as other states) will have to face increasing deficits in transportation revenues due to higher adoption of EV and AV technologies. Even if EV/AV adoption remains relatively low, the projected improvement in fuel efficiency of conventional vehicles alone will present significant challenges for traditional infrastructure funding model by continuing to erode gas tax revenues.

Some of the potential policy options that may help address tax revenue shortfalls, include: 1) adjusting gas taxes to address growing fuel efficiency of vehicles, 2) implementing EV fees and taxes, 3) implementing road use fees, or VMT fees, that are not based on fuel consumption, 4) employing public-private partnerships (PPP) to construct transportation infrastructure, and other approaches.

All of these approaches have their advantages and limitations that need to be evaluated carefully. Gas tax adjustment is relatively easy to implement, but such a measure is unlikely to provide a long-term solution (can only be effective in short-to-medium term). EV fees and taxes are very unpopular with EV owners and will face strong opposition from the growing number of EV customers. VMT fees, while providing equitable treatment of all road users, regardless of vehicle fuel efficiency, fuel or propulsion type, also have privacy implications that extend beyond the issue of revenue collection and allocative efficiency that will have to be addressed. PPP model for funding transportation infrastructure often faces negative public perception since it allows the private sector to profit from the public-sector investment. Finally, some of these options will involve uphill political battles, so their implementation and success will depend heavily on political will and the ability of decision-makers to demonstrate the urgency of proposed measures.

Conclusions

Although currently EVs have a relatively small impact on Florida state transportation revenue, fuel tax revenue losses from increased electric VMT are projected to increase from $9.5 million in FY 2019–2020 to $121 million by FY 2029–2030, totaling over $583 million for the ten-year period. The increased adoption of EVs, that will likely reach critical mass by 2030–2035, is projected to result in substantial tax revenue losses. By 2048, the total loss of tax revenue associated with the use of EVs is projected to reach $1.2 billion annually.

Tax revenue loss from AVs is projected to be insignificant during the first half of the 30-year forecast period but will accelerate in later years, reaching $969 million in 2044–2045. The period 2027–2028 through 2047–2048 will see increased AV adoption and market penetration, which will accelerate revenue losses. The cumulative impact of AV VMT on Florida transportation funding shortfall is projected to reach almost $9.0 billion, in constant 2018 dollars, for the period of 2018–2048.

The combined effect of increased EV and AV market penetration on total transportation revenue collection in Florida is projected to reach $18.3 billion for the entire period of 2018–2048, including $5.3 billion loss in federal transportation taxes, $9.7 billion loss in state transportation taxes and $3.3 billion loss in local use and local option taxes. At the end of FY 2027–2028, lost revenues due to the adoption of EV and AV technologies are not expected to exceed 1.3% of total fuel-based tax collections. By 2048, the projected rapid increase in EV and AV adoption in Florida will substantially increase revenue losses that are forecasted to reach 26% of the total fuel-based transportation revenues in Florida. Given the constantly growing transportation revenue shortfall, there will be continuous pressures on future legislative bodies to increase tax and fee rates or transfer funds away from other programs and into transportation, or to accept the consequences of degradation in transportation service levels.

In addition to gas tax revenue losses due to increased eVMT, wider adoption of EVs and AVs may require additional infrastructure investment to accommodate these technologies. For example, adequate public charging infrastructure will be required to support a large EV fleet. Additionally, upgrades to pavement markings and signage may be needed to enable vehicle automation technologies to recognize lane boundaries, pavement edge and road signs in all weather conditions.

It is expected that most of the benefits of AV adoption will be realized only after a large share of vehicles on the road are equipped with automation technologies. Similarly, the infrastructure investment requirements associated with AV technologies are expected to be rather minor in the short-to-medium term. The need for a relatively significant amount of infrastructure investment to address AV technologies will likely arise after 2040.

Future legislative bodies will encounter continuous pressure to increase tax and fee rates or transfer funds away from other programs and into transportation. While federal, state, and local legislative bodies in the U.S. have demonstrated a propensity in recent years to partially accommodate transportation funding shortfalls, continued ad hoc adjustments may become increasingly difficult to achieve as vehicle fuel efficiency continues to improve and EVs and AVs gain market share.

References

AAM – Alliance of Automobile Manufacturers (2019) *Advanced technology vehicle sales dashboard*. Retrieved from: https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/. (Accessed 15 March 2019.)

AFDC – Alternative Fuels Data Center (2019) *Alternative fueling station locator*. U.S. Department of Energy. Retrieved from: https://afdc.energy.gov/stations/#/find/nearest. (Accessed 21 April 2019.)

Bansal P, Kockelman KM (2017) Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy and Practice* 95: 49–63.

Bierstedt J, Gooze A, Gray C, Peterman J, Raykin L, Walters J (2014) *Effects of next-generation vehicles on travel demand and highway capacity*. Retrieved from: https://orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf(Accessed 22 January 2019.)

CARB – California Air Resources Board (2017) *Midterm review report: advanced clean cars*. Sacramento, CA: CARB.

EIA – U.S. Energy Information Administration (2018) *Annual energy outlook 2018 (AEO 2018)*. Washington, DC: Office of Integrated and International Energy Analysis.

EPA – Environmental Protection Agency (2016) *Light-duty automotive technology, carbon dioxide emissions and fuel economy trends: 1975 through 2016*. EPA.

Fagnant D, Kockelman K (2015) Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice* 77(Jul): 167–181.

FDOT – Florida Department of Transportation (2017) *Transportation funding sources*. Tallahassee: Office of the Comptroller.

Haboucha C, Ishaq R, Shiftan Y (2017) User preferences regarding autonomous vehicles. *Transportation Research Part C: Emerging Technologies* 78(May): 37–49.

Harper CD, Hendrickson CT, Mangones S, Samaras C (2016) Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. *Transportation Research Part C: Emerging Technologies* 72(Nov): 1–9.

Howard D, Dai D (2014) Public perceptions of self-driving cars: the case of Berkeley, California. In *Transportation Research Board 93rd Annual Meeting*. Washington, DC.

Kyriakidis M, Happee R, de Winter J (2015) Public opinion on automated driving: results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour* 32(Jul): 127–140.

Loveday S (2019) Monthly plug - In EV sales scorecard - Archive. InsideEVs. Retrieved from: https://insideevs.com/news/344006/monthly-plug-in-report-card-archive. (Accessed 21 September2019.)

Lutsey N, Nicholas M (2019) *Update on electric vehicle costs in the United States through 2030*. Washington, DC: International Council on Clean Transportation.

Nielsen TAS, Haustein S (2018) On sceptics and enthusiasts: what are the expectations towards self-driving cars? *Transport Policy* 66(Aug): 49–55.

Nordhoff S, de Winter J, Kyriakidis M, van Arem B, Happee R (2018) Acceptance of driverless vehicles: results from a large cross-national questionnaire study. *Journal of Advanced Transportation* 2018: 5382192.

SAE – Society of Automotive Engineers (2018) *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*. SAE.

Schaller B (2018) *The new automobility: lyft, uber and the future of American cities*. Brooklyn, NY: Schaller Consulting.

Schoettle B, Sivak M (2014) A survey of public opinion about connected vehicles in the U.S., the U.K., and Australia. In *International Conference on Connected Vehicles and Expo*, *Vienna*, *Austria*.

Trommer S, Kröger L, Kuhnimhof T (2018) Potential fleet size of private autonomous vehicles in Germany and the US. In G Meyer, S Beiker (eds.), *Road Vehicle Automation 4*, 247–56. Cham: Springer International Publishing.

US Census – U.S. Census Bureau (2018). *Selected economic characteristics, 2012–2016 American community survey 5-year estimates*. Washington, DC: US Census.

Zmud J (2016) Self-driving vehicles: determinants of adoption and conditions of usage. *Transportation Research Record: Journal of the Transportation Research Board* 2565(1): 57–64.