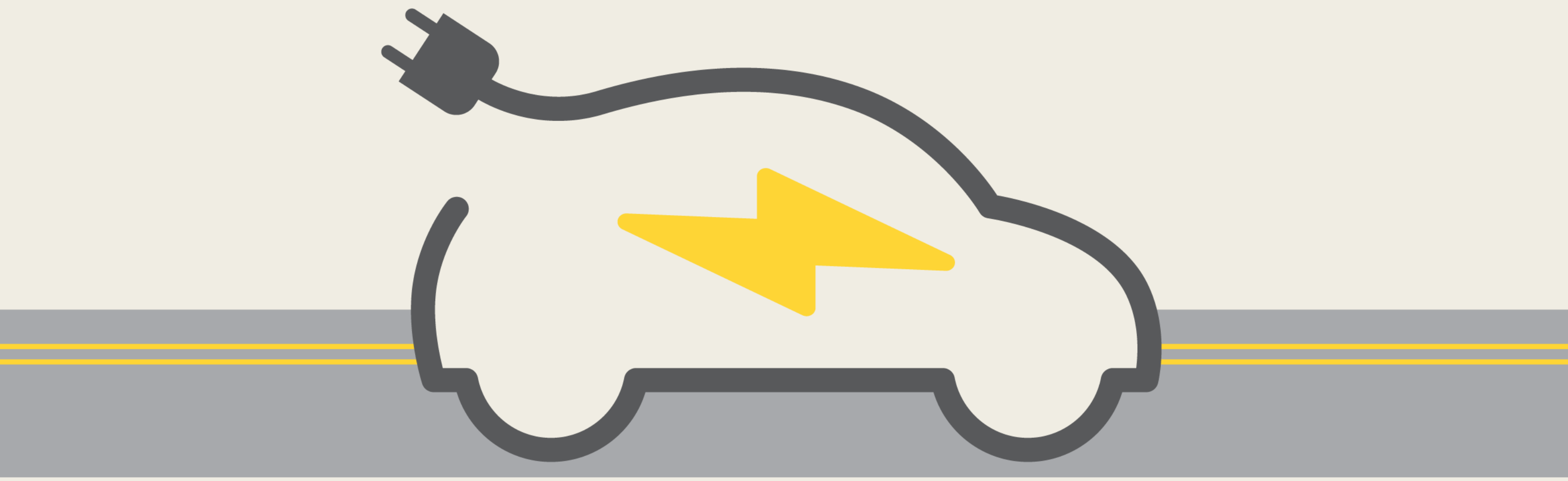
Potential Impacts of Autonomous Vehicles on Tennessee's Economy



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INTRODUCTION

Artificial intelligence (AI) and emerging technologies more broadly are rapidly developing and changing the types of goods and services that people demand and the ways in which they are produced and received. As a result, employment in many industries and occupations is being disrupted. The transitions are likely to accelerate during the next decade, further affecting nearly every aspect of life and work. The outcome is Tennesseans can expect the coming decade to be filled with precipitous changes that open new opportunities but also eliminate jobs, companies, and potentially industries.[1] The state must evolve by changing the way students and adults are trained and educated, the infrastructure that is built, and the regulations put in place. Workforce development and policy must change at an unprecedented pace if Tennessee is to remain a place where people can achieve highly successful careers and lives and businesses can be productive and competitive in a global environment.

This paper focuses on one emerging technology: Autonomous Vehicles (AV) and their potential to impact Tennessee. AVs are only one form of AI, but they are particularly important because they impact a sizeable share of Tennesseans across the spectrum of skills, occupations, and geography. This report seeks to identify the current importance of vehicles to Tennessee employment and how AVs will change more than a century of development and integration of vehicles in the state's economy. Some of the changes are already underway as evidenced by Volkswagen's focus on manufacturing electric vehicles and its decision to add an electric vehicle line to its Chattanooga facility. The recent location of an electric battery plant in the state is another example.

The report includes sections on the importance of vehicle manufacture, support and use to Tennessee employment, the likely ways AVs will develop, the industries and occupations that will be affected by the transition to AVs, and the general order in which the effects will be felt. Identification of the industries that will be affected provides a baseline to understand the current role of vehicles in the economy and a means to track how the state is being affected over time as employment shifts are measured in coming years. But, the paper makes no attempt to estimate the net effect of AVs and other technologies on employment, as jobs will develop in other industries so the net effect on jobs will be smaller than the total number of jobs at risk. The key point is that the new jobs that will likely develop in other industries will require very different skills than the jobs being lost. Also, the change in jobs will be faster than during previous large economic transitions, and the geographic, skilling and industry mobility of workers is probably too slow to expect a smooth shift into other industries and occupations. Public sector production will be impacted significantly because vehicles are important inputs in providing many state and local government services. On the revenue side, Tennessee, like all states, has linked a large share of taxes to vehicles, and we provide simulation results on how taxes will be affected by this emerging technology.

Further, in many cases AVs are more likely to alter how work is done rather than the number of jobs. Recent research focuses on the tasks that are performed rather than the jobs (for example, see Muro, et al, 2019 and Acemoglu and Restrepo, 2019). Jobs may be eliminated in cases where all of

[1] See Manyika, et al. (2017) for discussion of many areas where change can be expected.

the tasks are eliminated by AVs, as could happen with taxi or truck drivers. On the other hand, AVs may simply replace certain tasks for other positions, such as for ambulance and police drivers. Whether the total number of positions are lost depends on how demand for the services responds to the greater efficiency in delivering the related services.

We are at the front end of the AV era, which allows the state to anticipate coming changes and create an environment that permits Tennessee to be a leader in development, production and implementation of AVs. The best course is for Tennessee to support and encourage the AV industry's development and adoption. Attempts to discourage the industry risk relegating the state to being a follower in an industry that will develop in other states and countries regardless of what Tennessee chooses to do. Further, the state needs a plan for mitigating effects on workers as their jobs are radically changed or eliminated. Education and training for new jobs, information on where jobs are available, and other means should be key elements of a plan to help workers across many industries transition. We are still guessing as to when AVs will become a significant part of life and the pace at which the industry will develop, but we expect AVs to be a significant component of transportation by this decade's end. In any event, the extent of impacts on the economy is the same whether AVs are adopted quickly or slowly. The only difference is how long it takes for the effects to be felt.

STATE OF THE MOTOR VEHICLE INDUSTRY IN TENNESSEE

Automotive Employment in Tennessee

The automobile—a darling of 20th-century innovations—has been an expanding engine of economic activity in Tennessee during the past several decades. Its use and production have led to an extensive transportation cluster that spawns employment across many industries and geographically across the state. The diverse motor vehicle sector in Tennessee covers many types of industries and employs hundreds of thousands of Tennesseans (see Table 1).

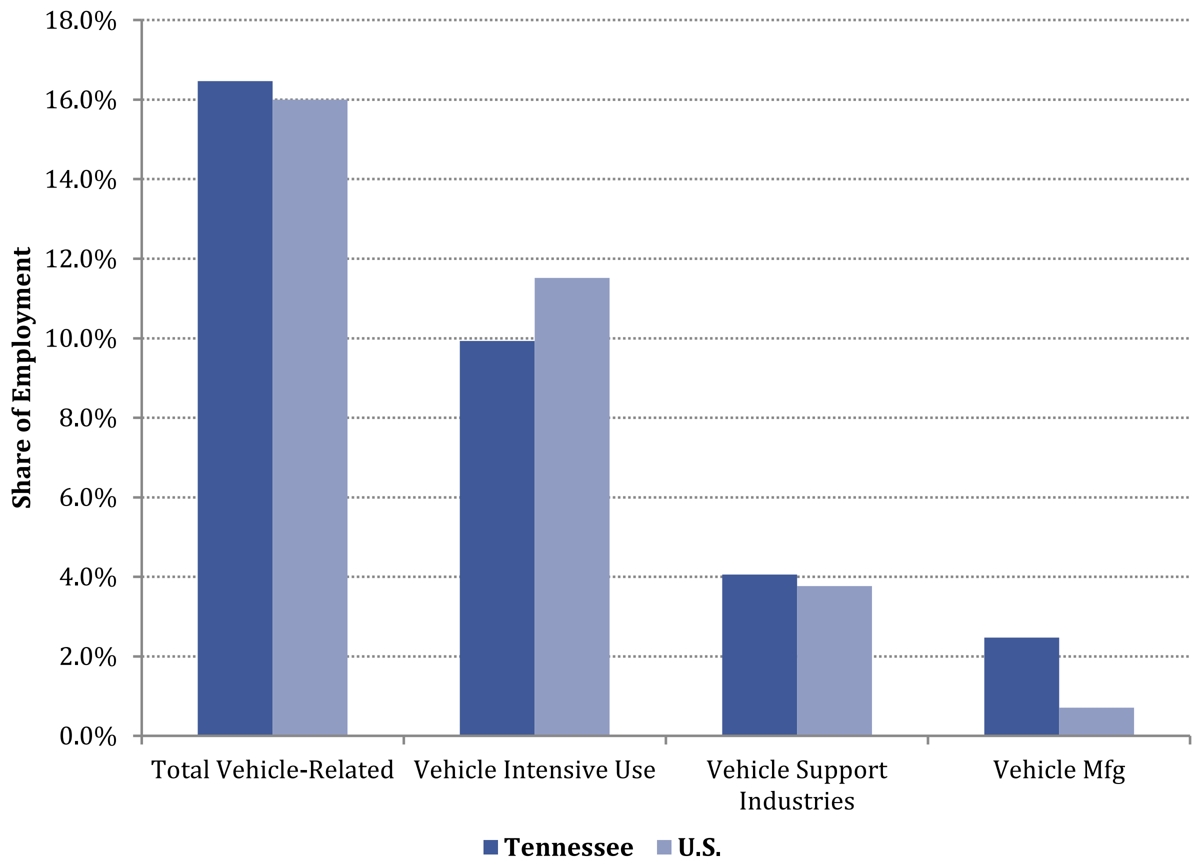
Table 1. Vehicle-Related Employment: Tennessee and the U.S., 2017

	Tennessee		U.S.	
Category	Employment	Share	Employment	Share
Total Employment	**2,930,932**	**100.0%**	**143,859,855**	**100.0%**
Vehicle Manufacturing	72,507	2.47%	1,023,674	0.71%
Vehicle Support	118,993	4.06%	5,425,489	3.77%
Vehicle Intensive Use:				
Motor Vehicle Operators and Other On-the-Job Drivers	291,000	9.93%	16,571,180	11.52%
Total Vehicle-Related Employment	**482,500**	**16.46%**	**23,020,343**	**16.00%**

Note: see footnote #2 for a complete explanation of employment data category definitions.
Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages; Bureau of Labor Statistics, Occupational Employment Statistics.

For purposes of this report, we divide vehicle-related employment into three categories: vehicle manufacturing, vehicle intensive-use occupations, and vehicle support industries. Appendix A contains a full list of the industries and Appendix B provides a list of vehicle intensive occupations.[2] Tennessee's vehicle-related employment accounts for 16.5 percent of total employment (Table 1 and Figure 1), meaning nearly 1 out of every 6 Tennesseans' jobs is tied closely to the vehicle sector as a producer, supporter, or intensive user. Tennessee's overall linkage to vehicles is somewhat greater than the national average of 16.0 percent.

Figure 1. Vehicle-Related Employment as a Share of Total Employment, 2017



Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages; Bureau of Labor Statistics, Occupational Employment Statistics.

Tennessee's vehicle manufacturing is a primary catalyst of the state's continued economic growth

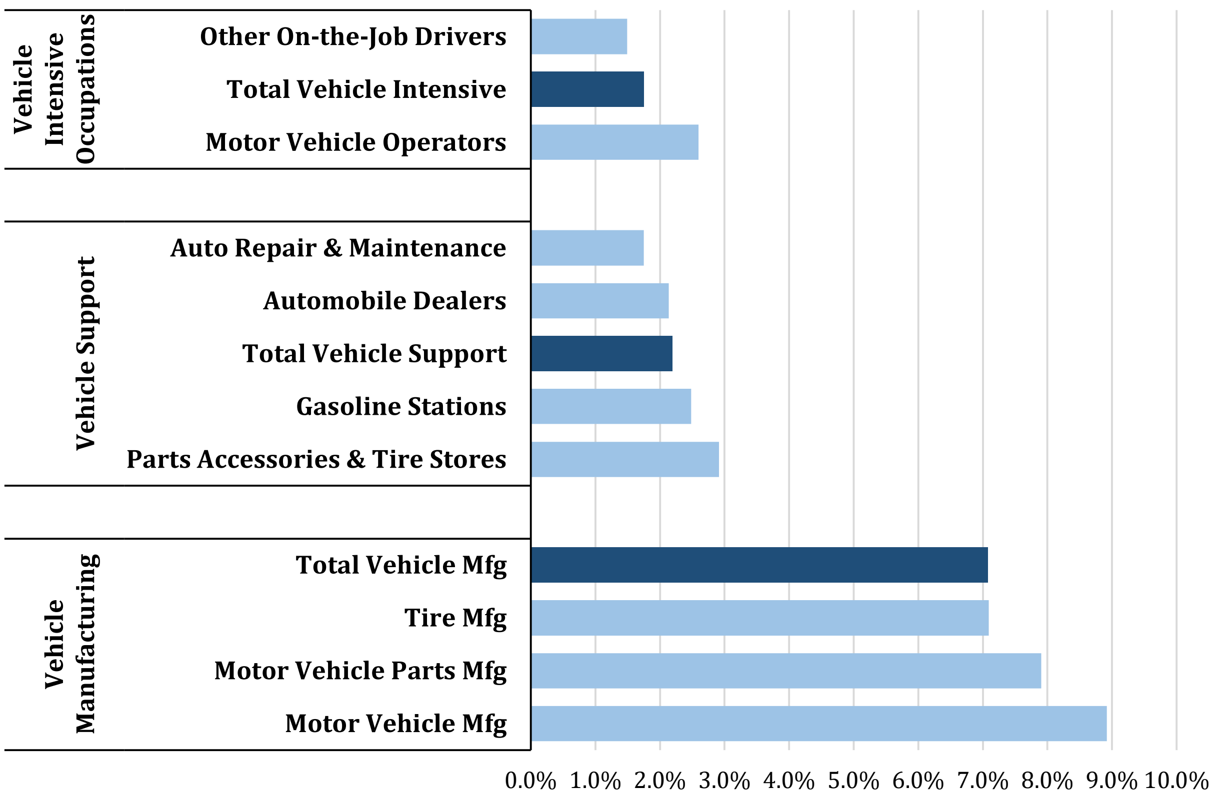
[2] This report uses two distinct datasets from the Bureau of Labor Statistics (BLS): the Quarterly Census of Employment and Wages (QCEW) and the Occupational Employment Statistics (OES) survey program. QCEW employment data are collected from establishments covered by unemployment insurance programs and are available *by industry*. QCEW employment data are used in this report for vehicle manufacturing and vehicle support industries. The OES program produces employment and wage estimates *by occupation* for nonfarm establishment workers (employment *by occupation* is not available from QCEW). Occupations that require driving a vehicle are present in multiple industries. The two data sets are aggregated to measure the overall importance of vehicles. Summing vehicle-related industry employment (QCEW) and multi-industry driving-related occupational employment (OES) undoubtedly results in some double counting, but both sets of employment data are necessary to capture all vehicle-related employment.

and is the area where Tennessee has a very large relative concentration of workers, but Tennessee has more jobs linked to vehicle support industries and intensive user occupations. The remainder of this section discusses each of these employment categorizations.

Vehicle Manufacturing

In total, 72,507 vehicle manufacturing jobs existed in Tennessee in 2017, including jobs in motor vehicle assembly and automotive parts industries. Tennessee vehicle manufacturing makes up 7.0 percent of total vehicle manufacturing jobs in the U.S. (Figure 2), compared with the 2 percent of the nation's population that is in Tennessee. Tennessee is much more reliant on vehicle manufacturing than the national average (Table 1). Tennessee motor vehicle manufacturing experienced very rapid 2.2 percent annual growth from 2007 to 2017, which covers an entire business cycle, and substantially higher than the 0.3 percent decline in the U.S. (Figure 3) and faster than the 0.7 percent average annual growth for Tennessee jobs.

Figure 2. Vehicle-Related Employment: Tennessee as a Share of the U.S., 2017



Note: Major employment categories only. For a full list of industries and occupations, see appendices A and B.

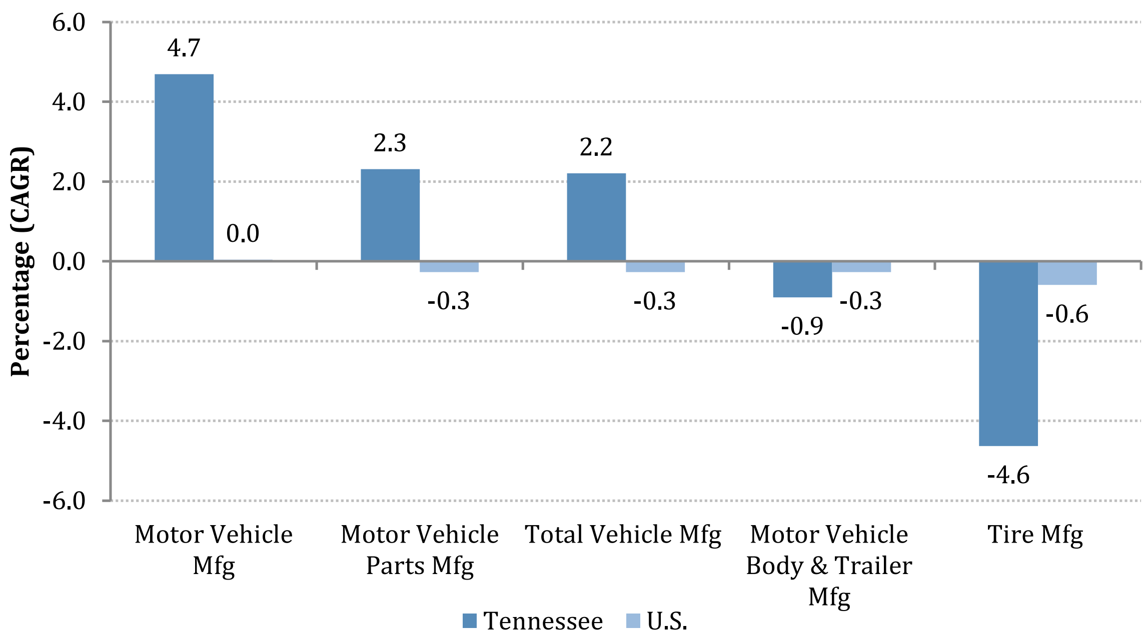
Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages; Bureau of Labor Statistics, Occupational Employment Statistics.

Motor Vehicle Assembly

Tennessee has become a major national player in motor vehicle assembly. In 2015, 6.3 percent of cars produced in the U.S. were made in Tennessee (TN ECD, 2016). Nearly 20,000 workers, or 8.9 percent of U.S. motor vehicle assembly workers, were employed in Tennessee in 2017 (Figure 2). Tennessee employment in motor vehicle assembly grew a robust 4.7 percent annually from 2007 to 2017 compared with no growth nationally during the same years (Figure 3), which means Tennessee has captured a growing share of national automotive manufacturing.

Recent announcements by Volkswagen and GM show that vehicle manufacturing growth remains strong in Tennessee. Volkswagen plans to hire another 1,000 workers for its plant in Chattanooga in order to produce the company's first electric vehicle in the U.S. (TN ECD, 2019). Likewise, GM is planning to add an additional 200 employees at its Spring Hill plant in order to begin production on the new Cadillac XT6 (TN ECD, 2019).

Figure 3. Vehicle Manufacturing Employment Growth: Tennessee and the U.S., 2007 to 2017



CAGR compound annual growth rate

Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages; Bureau of Labor Statistics, Occupational Employment Statistics.

Motor Vehicle Parts Manufacturing

In addition to robust motor vehicle assembly, Tennessee is home to over 900 auto parts suppliers that provide jobs for more than 46,000 Tennesseans. Again Tennessee is capturing a large share of national employment with nearly 7.9 percent of all U.S. auto parts workers employed in the state (Figure 2). Furthermore, Tennessee parts employment has been rising 2.3 percent annually compared to the 0.3 percent decline nationally (Figure 3).

Employment Distribution in Tennessee

Vehicle manufacturing is located throughout the state with major manufacturers in each of the largest four metropolitan statistical areas (MSA). As people and thus workers have migrated to cities, so have vehicle manufacturers. Much of the employment created by these manufacturers is around the largest MSA's, with major plants like Nissan in Rutherford County, Denso in Blount County, Volkswagen in Hamilton County, and GM in Maury County (Figure 4).

This is not to say that vehicle manufacturing is not of outsized importance to many rural counties. Quite the contrary, employment in rural counties is often dominated by vehicle manufacturers. For example, Yorozu Automotive in Warren County, Great Dane in Scott County, and Denso in McMinn County together employ thousands of workers. Job displacement in many rural communities would likely be very difficult to offset given the relatively small job creation in rural places in recent years.

Vehicle Intensive-Use Workers[3, 4]

The largest share of vehicle-related employment is in vehicle intensive-use occupations. This category includes motor vehicle operators and on-the-job drivers, both of which include many sub-occupations (Appendix C). Overall, Tennessee relies less on vehicle intensive-use workers than the national average (Table 1), though Tennessee has a much larger share of truck drivers than the national norm.

Motor Vehicle Operators

Throughout history, Tennessee's geographic location has made it an important state for travel. Large portions of the national Interstate Highway System run through the state with a majority of the U.S. population less than a day's drive away. This makes Tennessee an ideal state for transportation industries. Given its geographic advantage, many transportation industries make their home in Tennessee, and transportation company headquarters are spread all across the state. FedEx in Shelby County, U.S. Xpress Enterprises in Hamilton County, and Averitt Express in Putnam County are but a few of the companies headquartered in the state.

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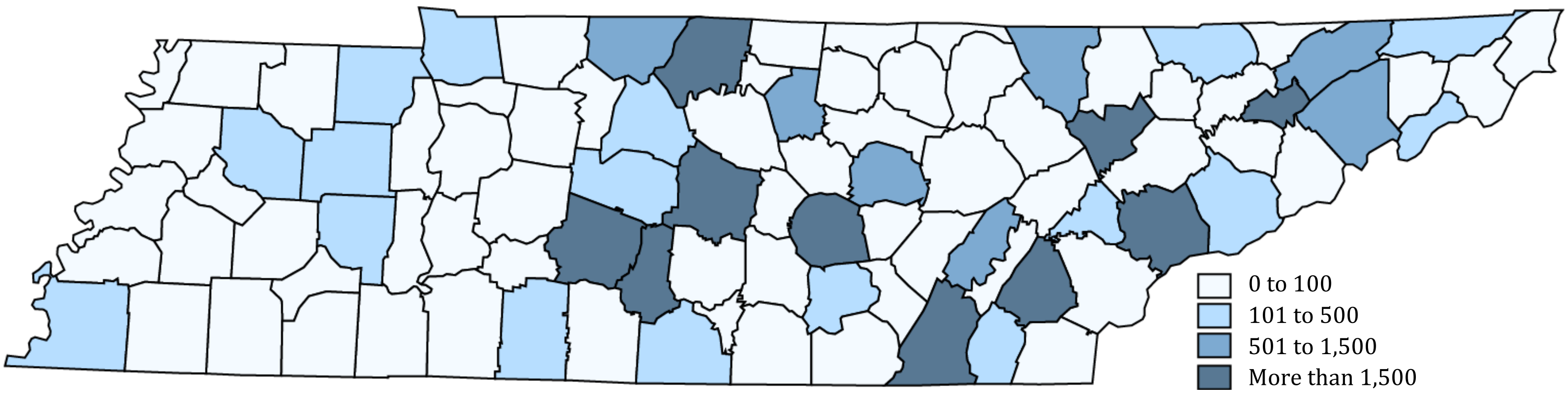
[3] As noted in footnote 2, data used in this section are Occupational Employment Statistics (OES) survey program data. Therefore, employment by the occupations listed in this section may have some overlap with industries in both the vehicle manufacturing and vehicle support categories resulting in some double counting in aggregate totals. However, we expect the overlap to be minor. Overlap does not occur between the vehicle manufacturing and vehicle support industries since each industry is distinct in the QCEW data. Similarly, each occupation is distinct so no double counting should occur by occupation. However, workers in driving intensive occupations may overlap to a limited extent with the industry categories; e.g., a truck driver working for a vehicle manufacturing company. However, the overlap would only take place if the worker is directly hired by the manufacturer and does not occur if the worker is hired by a transportation company external to the vehicle manufacturing company.

[4] Occupation data for Tennessee are also available from the Tennessee Department of Labor and Workforce Development. We chose the OES data because they allow a consistent comparison with U.S. data.

Figure 4. Automotive Employment by County

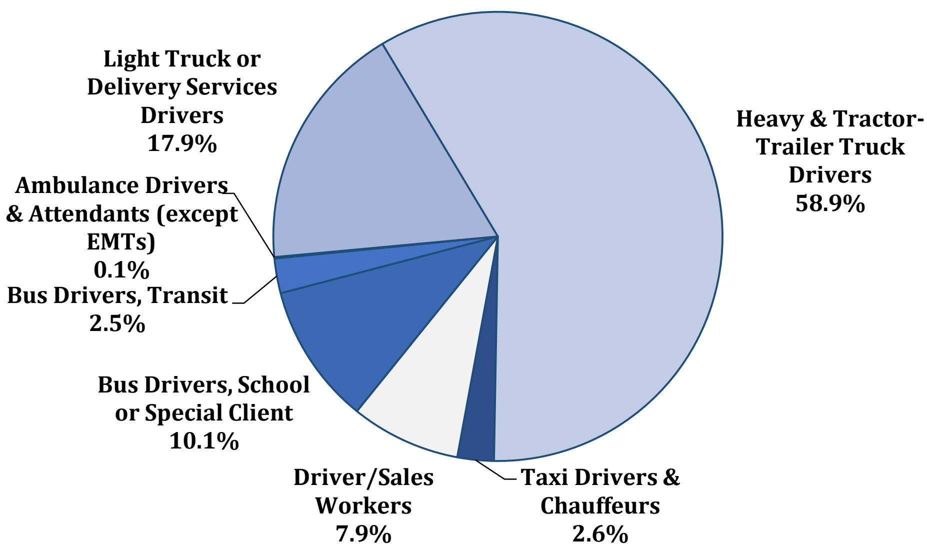


Source: Tennessee Department of Economic and Community Development, https:/tnecd.com/industries/automotive/, retrieved March 2019.

In total, there were 102,510 motor vehicle operators in Tennessee in 2017 accounting for 3.5 percent of all jobs in the state. Unfortunately, employment in these industries declined 0.3 percent annually over the past decade versus a 0.3 annual increase in the U.S.

Trucking represents most of the state's motor vehicle operator employment (Figure 5). Tennessee's employment in truck transportation makes up 3.5 percent of the national truck transportation workforce—nearly twice the state's 2 percent population share—and accounts for 60,350 workers. (See Appendix B for a listing of motor vehicle operator occupations.) In 2015, Tennessee ranked 1st in the southeast and 6th in the nation in total truck transportation (TN ECD, 2016). However, Tennessee has seen slower growth than the U.S. in trucking employment. Tennessee employment fell 0.1 percent annually from 2007 to 2017 versus a 0.3 percent increase for the U.S.

Figure 5. Distribution of Motor Vehicle Operators: 2017



Source: Bureau of Labor Statistics, Occupational Employment Statistics.

All other motor vehicle operator occupations in the state provided jobs for 42,160 Tennesseans and combined declined 0.5 percent annually between 2007 and 2017 versus an annual increase of 0.3 percent for the United States. Included in this number are taxi drivers and chauffeurs. Tennessee has 2,690 taxi drivers and chauffeurs, which represent 4.5 percent annual growth over the past decade. These workers are mostly taxi drivers and their ranks continue to increase, though the number understates employment in this industry as contractors who work for ridesharing companies like Uber and Lyft are not captured in these data. We would expect both employment and corresponding growth rates to be much higher if ridesharing could be included.

On-the-Job Drivers

In addition to motor vehicle operators, a large number of occupations require extensive driving, even if the main service is not transportation of goods or people from one destination to another.

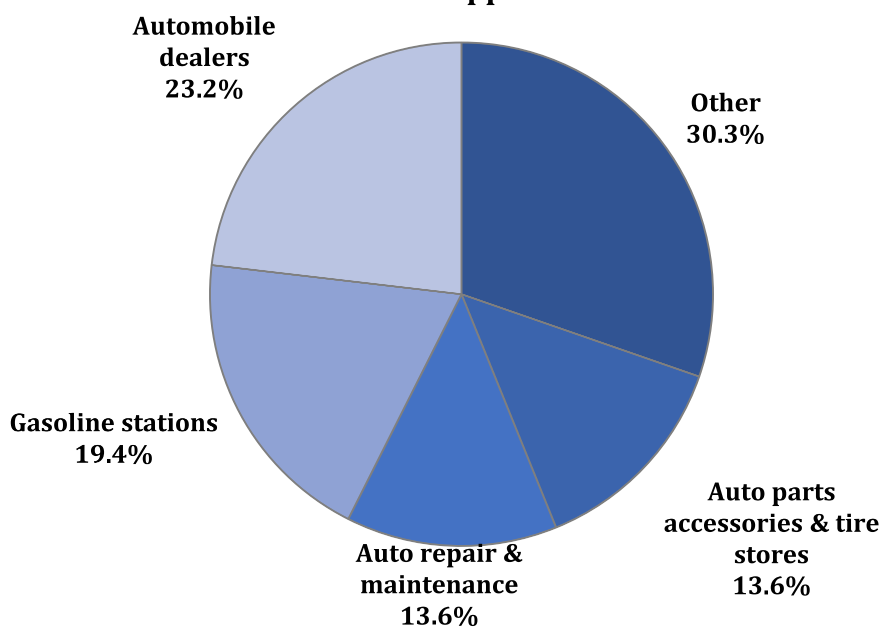
For example, plumbers, animal control workers, and ambulance drivers use vehicles extensively, but they are not classified as motor vehicle operators. We estimate the number of "on-the-job drivers" in Tennessee by following the U.S. Department of Commerce that identified 119 O*NET occupations that included driving as an important/required part of the job (Department of Commerce, 2017).[5] The role of vehicles in these occupations varies, but travel and vehicles are key to the job in every case.

These on-the-job drivers are a significant part of Tennessee's economy providing 188,490 jobs and accounting for 6.4 percent of all workers in the state. Tennessee employment in this category is likely understated because data are not reported for some occupations. Tennessee saw a 1.2 percent annual increase from 2007 to 2017. This growth was similar to the U.S. which saw a 1.3 percent annual increase over the same period.

Motor Vehicle Support Industries

Motor Vehicle Support contains a variety of diverse industries that exist because vehicles are owned and operated within the state.[6] Automobile dealers, gasoline stations, auto repair and maintenance, and auto parts accessories and tire stores comprise 70 percent of employment in this category (Figure 6). In total, industries that support motor vehicles provide 118,993 jobs for Tennesseans and account for 4.1 percent of all employment in the state (Figure 1). Employment in this category has grown just under 1.0 percent annually for the past decade.

Figure 6. Distribution of Motor Vehicle Support Industries



Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

[5] Please see Appendix C for a full list of occupations.
[6] For a full list of these industries please see Appendix A.

FUTURE TENNESSEE VEHICLE EMPLOYMENT AND AUTONOMOUS VEHICLES

The previous section demonstrates the transportation sector's importance to Tennessee and the nation. Tennessee stands out in the role that vehicle assembly and component parts manufacturing plays, but employment in various vehicle intensive-use occupations and vehicle support industries is much larger than in manufacturing. This section addresses how Tennessee's transportation industry will be affected by the advent of autonomous vehicles.

The economic effects are important to identify so that government, people, and businesses can plan more carefully for future labor force needs and changing economic prospects. We are unable to anticipate the net effect that AVs could have on jobs, but it will certainly be less than the gross jobs at risk that are identified here. Many jobs might be created in new businesses that support the AV industry, including IT. Other types of industries may also grow and provide jobs in unrelated occupations and businesses. Further, as described above, in many cases AVs will change how work is done rather than replace jobs. AVs, like other technologies will make workers more efficient, and this may increase or decrease the number of positions. So, this report identifies the maximum share of jobs that might be disrupted, but does not seek to measure the net effects on jobs as other opportunities develop. Still, at a minimum, large transitions will dramatically affect many people, occupations, and communities, and now is the time to begin planning for appropriate policy and for education and training responses.

This paper focuses on potential employment and tax transitions, but the intent is not to build a case for discouraging the production or use of AVs. Many benefits can be expected, and AVs will ultimately be very good for the economy and most people though some will probably be harmed, such as those who lose their businesses and jobs as the associated economic transitions take place. Further, there is little that could be done to stop development and adoption of AVs around the world. Tennessee and the U.S. must continue to encourage and support this rapidly emerging industry if we are to be a leader in the industry. Otherwise we could simply yield this potentially giant industry to other countries around the world.

Some of the benefits of AVs include:

- Shared vehicle use will lower the cost of mobility. – RethinkX (2017) optimistically estimates that the average household can save $5600 per year with shared mobility.
- Electric vehicles will be less damaging to the environment.
- Human time spent in vehicles will be more productive as people commute, shop, road trip and so forth.[7]
- Traffic accidents will be significantly lessened and people will travel more safely.
- Congestion could ultimately be lowered as AVs can operate more closely relative to other vehicles and can drive less erratically.

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[7] A recent survey found that 59 percent of people between 22 and 37 would rather be using their driving time in more productive ways. The percentage is high given that people have not seen the technology yet, though 45 percent regularly use ride sharing. See https://www.lincolninst.edu/publications/articles/driverless-ed.

- Space currently used for parking will be freed up for more productive purposes.

The Future of AVs

Many light vehicles today have enhanced technology and AI built in. The issue arises as to which vehicles should be thought of as autonomous. The following descriptions have been broadly adopted as a useful way to categorize vehicles. We regard Categories 4 and 5 as AVs:[8]

- **Category 1**: Some steering and acceleration/deceleration technologies that require the driver to be fully engaged.
- **Category 2**: Partial automation as it expands the capabilities in Category 1 and requires the driver to be fully engaged.
- **Category 3**: Category 2 and monitoring of the driving environment. The driver is less engaged but may be involved in difficult environments.
- **Category 4**: Category 3, but the vehicle handles difficult environments if the driver does not. Requires limited driver monitoring.
- **Category 5**: Automation of all systems and allows the driver to be optional.

How AVs affect Tennessee's economy depends very heavily on their future characteristics and the environment in which they operate. AVs will be very disruptive if they markedly change the vehicle structure, operation, ownership and other aspects of transportation. The answers to some key questions about AVs will determine the ways in which and the extent to which they impact the economy. A few such questions include:

- Are they owned individually or in fleets?
- How many AVs are necessary to replace each self-driven vehicle?
- Are they built with electric or internal combustion engines?
- Do they impact the amount traveled?
- What regulatory structure is in place?

We conclude that the likely scenario is one where future mobility is substantially accomplished by electric AVs that are owned in fleets. This scenario is key to the expected fiscal and economic effects because fewer vehicles will be needed, the vehicles will rely on different component parts, and fossil fuel will be less important. The tax system focuses on taxing large numbers of internal combustion engine vehicles, so tax revenues are significantly impacted. Many economic sectors, such as manufacturing, are also impacted as fewer, differently structured vehicles are manufactured and used.

Fleet Ownership

Uber is seeking to unbundle mobility according to Dara Khosrowshahi, Uber CEO.[9] Unbundling can transform mobility much more broadly than people riding in AVs rather than owning a car or using public transit. It includes bicycles and scooters, delivery such as Uber Eats and Uber Freight, and

[8] See Society of Automotive Engineers (2014).
[9] Dara Khosrowshahi interview on CNBC Squawk Box, May 10, 2019.

other mobility. Young people, previously underserved people, such as the elderly and very young, and those living or working in very large cities are obvious examples of initial users, but demonstrated safety and cost savings could accelerate use across the spectrum.

Ownership is likely to change radically, or at least many vehicles will probably operate as part of a network rather than as a series of independent vehicles. We expect convenience and cost savings as mobility is unbundled to encourage people to use fleet owned/shared vehicles. Cost can be dramatically lowered if vehicles become fully part of the sharing economy where riders simply use AVs for mobility whenever demanded and where the AVs operate as part of a network.[10] Some vehicles could still be individually owned by people willing to bear the cost of owning and using their own vehicle. Others may own an AV privately and make rides available through an app, much like occurs with Airbnb. Some individual ownership of vehicles is certainly likely to occur during the transition and in areas where a network does not develop in the early years of AVs. For example, many rural places may be served by individually-owned vehicles until a scale is reached that makes it profitable for fleet companies to operate in the area.[11]

In principle, all AVs could be owned individually and operated as part of a network, as occurs through the Uber and Lyft apps. Effectively, the app connects owners and users and allows privately-owned vehicles to operate as a fleet. However, direct fleet ownership of AVs seems likely to offer many scale benefits such as repair, charging, larger purchasing power, ensuring sufficient supply in peak times, facilitating long trips, and so forth. As a result, we expect fleet ownership to be the dominant model except for narrow niches that might be filled by individual ownership. We anticipate a broad system that operates on a very wide geographic and mobility scale but with the vehicles owned by the sharing company and operated as part of a network. The ownership model differs from today when vehicle sharing is facilitated through individual driver/owners.

The experience of driving and owning particular vehicles is very important to many people and has long been part of our culture. Vehicles often transcend simple mobility and become a part of how people see themselves and their image. But AVs will not be driven, people will use them for mobility. Will this distinction alter the way people perceive vehicles so that they are willing to use them as a tool and not a defining part of their individuality? Of course, different qualities of service will still exist with AVs giving people the opportunity to differentiate themselves to some extent. We expect the safety and cost savings ultimately to overcome the cultural forces to drive one's own vehicle and result in AVs owned in fleets.

Vehicles could become much more like a commodity when fleets dominate access to mobility and the demand for vehicles becomes a derived demand that depends on final demand for mobility (rides). A modest number of mobility providers are likely to survive, and fleet companies may vertically integrate to own vehicle production, service delivery, and other parts of the supply chain. A vertically-integrated supply chain with AVs as commodities could ultimately lower per-vehicle

[10] Naughton and Welch (Bloomberg Business, Feb 28, 2019) cite Mark Wakefield stating that the saved labor cost with AVs can reduce taxi ride costs by 60 percent.

[11] The challenge of extending broadband access to rural places provides an example of problems of developing fleet AV systems in rural places. Rural residents may also find AVs less useful, at least in the beginning, as they are likely to be designed based on urban experiences.

costs, at least relative to a model where they are individually owned. This model will radically change manufacturing and buyer/seller relationships since the producers no longer need to appeal to individual buyers but instead to providers of mobility.

Number of Vehicles Necessary

The number of AVs that will be necessary to provide the demanded mobility determines the number of vehicles and parts that will be produced and some of the tax revenues from vehicles. We expect fewer AVs will be necessary to replace the current vehicle stock because fleet vehicles can be driven much more intensively than current self-driven, individually-owned vehicles that sit most of any 24-hour period. For example, taxis in New York City drive 60-70,000 miles per year and last 6-7 years.[12] So the average taxi has a life of about 400,000 miles. Self-driven vehicles last about 12 years and are driven about 180,000 miles.[13] Many Tennessee cities likely have sufficient demand such that vehicles tied into a network could be driven similar numbers of miles per year as New York taxis, though from a national manufacturing perspective it is the entire nation (plus export demand) not Tennessee that is the relevant concern. If AVs have the same life as taxis, the difference in mileage life from the current stock suggests about 0.4-.045 AVs per current vehicle, assuming fully efficient mobility networks. Further, there is reason to believe AVs might have a longer life than taxis because there could be less damage from accidents, electric engines are much simpler and likely to last longer than internal combustion engine vehicles, and the fleet provider could be better able to maintain the vehicles and use smart systems in the vehicles to ensure maintenance happens as needed. Longer useful life for fleet vehicles means that even fewer are needed over time. On the other hand, changing technologies may lead to more frequent vehicle turnover if the enhancements are regarded as sufficiently large.

Fewer vehicles appear necessary to meet current mobility demands, but mobility demands may rise with AVs meaning more vehicle miles traveled (VMT). Currently, underserved groups such as the elderly, disabled, and young could gain considerable mobility with AVs raising per person VMT. Empty miles add VMT as vehicles travel to reach riders. Also, the ability to use time in the vehicle for a broad set of purposes rather than driving eases travel and effectively makes the opportunity cost of traveling lower. All of these suggest greater per person VMT, with less mileage looking for parking spaces being a modest offsetting tendency.

Pricing for fleet rides could alter incentives for greater VMT since mobility companies can be expected to price at marginal cost. People may currently be subject to cost illusion with travel, thinking that motor fuel is the main cost of driving when the real cost of travel includes depreciation of the vehicle, maintenance, insurance, parking and so forth. As a result, people may underestimate the real marginal cost of travel and recognition of the true cost might discourage some VMT at least initially. For example, an experiment in Oregon found that people drive 10-14 percent less when they are charged a VMT tax rather than pay the gasoline tax (Ratner, 2018), though the effects of AVs and pricing on VMT remains an important issue to continue analyzing. But the initial shock of facing marginal cost prices may erode to some extent, and VMT could

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[12] See Clements and Kockelman, 2017.

[13] See Davis, S.C., Williams, S.E. and Boundy, R.G. 2018.

ultimately go up over time.

Additional AVs are needed if people switch transportation modes to AVs, such as when they transition from public transit to AVs.[14] Slow movement from public transit appears to already be underway as ridesharing and other forms of mobility (such as bicycle and scooter sharing) become available. AVs may enable more shifting but much of it is occurring anyway because of other forms of mobility and vehicle sharing. AVs that accommodate multiple passengers potentially allow for an AV version of public transit that does not require a requisite increase in the number of vehicles as AV usage grows, but many people will probably continue to prefer individual or family travel. The broader set of mobility options that is developing make it even more difficult to be definitive on the number of AVs that will ultimately be demanded.[15]

On net, we believe planning should be around a 25 percent increase in per-person VMT. When added to the estimate of 0.4 AV per existing vehicle given above, this indicates somewhere around 0.5 AVs are needed for every 1 self-driven vehicle.[16] This estimate suggests fewer people employed in the manufacturing of vehicles and parts regardless of how the tasks undertaken by manufacturing workers are affected by the technology. It also suggests less revenues from licenses, motor vehicle titles, motor vehicle registrations, and sales taxes on vehicle sales. Tire taxes could rise if VMT goes up and additional tires are needed.

Electric Vehicles[17]

Internal combustion engine (ICE) vehicles dominate the landscape today. However, the Boston Consulting Group states "As the transition unfolds, we expect pure ICE vehicles to decline in share from their current 95% of the global market to about half of all vehicles around 2030 (Mosquet, et al, 2018)." Maintenance, ability to operate as a network, and ease of recharging all suggest that AVs will be electric. Battery life becomes relatively less important in a network and with scale since charging can be accommodated within the system. For example, a long distance trip can occur by either getting a very quick charge during the trip or by changing the battery along the route. For within-city mobility, a network of vehicles allows some to be charged while others are providing rides without any loss of access to mobility.

Electric motors require far fewer parts than internal combustion engines. For example, BMW

[14] Graehler, Mucci, and Erhardt (2019) find that public transit ridership falls with access to Transportation Network Companies and bus ridership with access to bike sharing. The potential transit decline discussed in this section may depend more on access to TNC companies and ride sharing than on AVs per se. This may mean that much of any increase in VMT arising from reduced transit ridership may take place before AVs are introduced and is dependent on the sharing economy and not AVs.

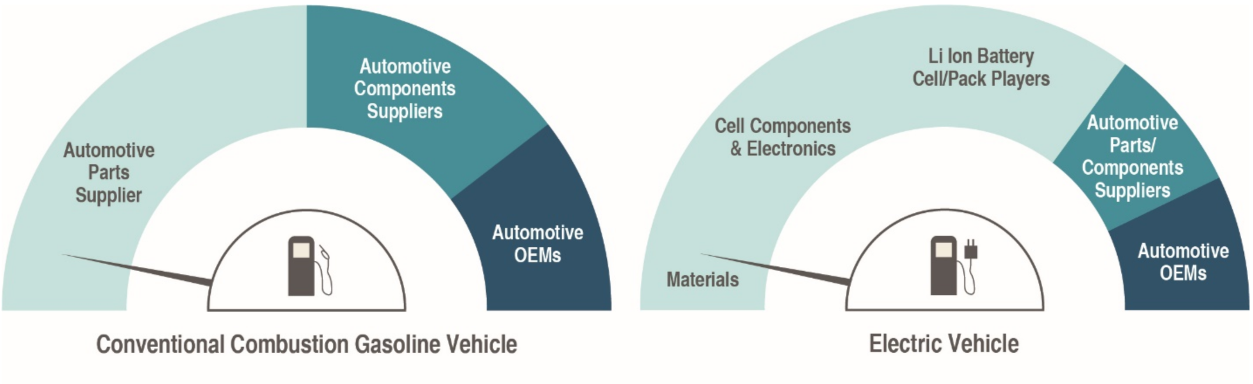
[15] Mobility as a service is a rapidly growing approach to meeting peoples' needs. Electric bicycles, scooters, three wheel scooters, and other forms of mobility evidence differing means to achieve this result. See https://www.fastcompany.com/90316775/is-it-time-for-scooters-to-be-put-in-their-place?, for example.

[16] VMT has been growing about 0.7 percent annually. Standard and Poor's (2018) expects a 5-20 percent increase in VMT with a 50 percent penetration rate for AVs. Clements expects a 20 percent increase in VMT.

[17] AVs could be powered by fossil fuels, though the discussion in this section assumes they will be electric. Impacts on manufacturing and some support industries will be lessened if fossil fuels are the primary power source.

General Works Chairman Manfred Schoch has observed that "An eight-cylinder engine has 1,200 parts that need to be assembled, and an electric motor only 17 parts" (Focus Online, 2016). As shown in the previous section, more than 46,000 workers in Tennessee are employed in parts manufacturing and many may lose their positions or transition to making very different parts. Again, this occurs because electric vehicles rely on fewer and different parts and not necessarily because of changes in the tasks undertaken by the workers. Figure 7 illustrates differences between internal combustion engine vehicles and electric vehicles.

Figure 7. Industry Structure for Conventional and Electric Vehicles



Source: https://www.iedconline.org/clientuploads/Downloads/edrp/IEDC_Electric_Vehicle_Industry.pdf.

A recent MTSU Bureau of Business and Economic Research study of foreign investment in the state found that Tennessee is already replacing many of these supplier jobs with others that supply electric cars and could supply AVs. The study found major investment by Nidec (electric motors), AtlasBX (car batteries), Denso (auto parts), Volkswagen (electric line at the vehicle assembly plant), and perhaps others in the production of parts and vehicles that could ultimately be components of AVs.[18]

Transitioning to electric engines is only part of how AVs will be different from the current stock, as much more extensive software must be incorporated in AVs. In this sense, Figure 7 fails to demonstrate how different the components of AVs will be from existing vehicles. Estimates are that vehicles are currently about 90 percent hardware and 10 percent software and AVs could be 60 percent software and 40 percent hardware.[19] Tennessee must help produce the software, computers, sensors and other parts if it is to remain a major producer of car inputs. The combination of needing fewer vehicle parts, together with the need to integrate different components such as battery and computer systems, may lead auto-manufacturers to look to electronic manufacturers who may already be producing the battery to also supply other components. The Bolt, an electric car produced by Chevrolet, illustrates the type of change that

[18] Volkswagen has announced plans to move dramatically towards electric vehicles during the next decade, https://www.wsj.com/articles/volkswagens-costly-bet-on-electric-cars-11552403871. India and China have also announced intention to move towards electric vehicles, strengthening this direction in worldwide production.
[19] See Clements and Kockelman, 2017.

could occur, since "87 percent of the Bolt's electric powertrain, battery and infotainment system are supplied by LG Electronics and LG Chem."[20]

Electric AVs have important implications for the tax revenues collected from transportation. Gasoline, special petroleum, and motor fuel taxes ultimately fall to zero as electricity is substituted for fossil fuel in vehicles. Tennessee imposes an electric vehicle fee, but the revenue per vehicle is only about two-thirds the amount collected per year from fossil fuel taxes given average vehicle travel and miles per gallon,[21] and this is without consideration of the dramatic increase in miles per vehicle that is expected with AVs. Shared revenues from TVA could rise some as electricity is used to power more vehicles.

Regulatory Structure

The adoption rate for AVs could be strongly influenced by the regulatory structure put in place by states and the federal government. Regulations permitting testing and operation of driverless vehicles on the roads must be developed and appropriate infrastructure must ultimately be built and enabled with suitable technologies. At least 29 states, including Tennessee, have enacted some legislation regarding AVs.[22] The federal government has also issued guidance through the National Highway and Transportation Safety Administration (NHSTA). The guidance indicates that states do not need permission to test or deploy AVs and makes it clear that federal guidelines are voluntary and do not include any compliance or enforcement provisions. This paper does not address the appropriate regulatory structure, but it is imperative that a safe, supportive regulatory structure be developed across the country that enables apt development of the industry and allows Tennessee to be a leader in this emerging industry.

Some may be inclined to impose a very restrictive structure on AVs or to seek prohibitive taxation to slow the employment and tax transitions that are described here. Tennessee and the U.S. operate in an international environment and countries such as China, Japan, and Germany (and the EU more broadly) are surely going to continue developing and implementing AVs. U.S. failure to keep pace could put us behind the industry's development in other countries and likely result in the U.S. becoming a follower rather than a leader in a rapidly expanding technology and industry.

Employment Implications of AVs

We divided vehicle-related employment into three categories above: vehicle manufacturing, vehicle support, and vehicle using. Each will be affected differently by the advent of AVs with some

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[20] Sedgwick, D. (2017, July 30). Which suppliers will survive the electric era? Retrieved August 15, 2018, from http://www.autonews.com/article/20170730/OEM05/170739947/which-suppliers-will-survive-electric-era.

[21] We estimate that the average driver of an internal combustion vehicle will pay $146 per year in gasoline taxes. The estimate assumes the average vehicle is driven 12,177 miles per year at 21.7 miles per gallon. Our calculations assumed the fully phased in $0.26 per gallon tax rate. Mileage data come from the U.S. Department of Transportation, Federal Highway Administration, *National Household Travel Survey (NHTS) 2009* and from the Bureau of Transportation Statistics.

[22] See http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

parts of each impacted very quickly and employment in others seeing modest effects for a considerable time. The timing of macroeconomic implications of AVs depend on the pace of adoption and transitions.[23] The pace of job losses and the transition in the way tasks are performed in many cases will be faster than the pace at which the vehicle stock moves from driven vehicles to AVs. Chris Pauly of HDR[24] illustrates that the adoption rate for new technologies has accelerated at a dramatic pace during the past several decades relative to earlier technologies in the 1900s, suggesting the possibility of rapid adoption. Still, we are still left with considerable uncertainty over how long it will take to realize the task changes discussed below.

Manufacturing Employment

Manufacturing will be altered both by the number of vehicles demanded and the change in components. Ultimately, vehicle manufacturing will decline if we are correct that fewer AVs will be necessary to replace each internal combustion engine vehicle, though it is possible that a modest spike in production/sales may occur as AV fleets are initially developed. Vehicle manufacturing/sales already appear to have peaked in the U.S. because of growing ridesharing, longer vehicle lives, long duration of the economic recovery. Otherwise, we would anticipate vehicle sales to remain at peak levels. There were 17.5 million light vehicle sales in the U.S. in 2016 with the sales averaging a seasonally adjusted 16.8 million annual rate in September and October 2019.[25] [26]

Job loss associated with the reduction in manufacturing will probably occur early in the AV era because vehicle buyers who would otherwise purchase traditional internal combustion engine vehicles might quickly realize that the resale market could be very thin in the future, causing buyers to be increasingly likely to keep and repair old vehicles rather than buy new ones. Similarly, many traditional component parts could be eliminated and this will be combined with the reduction in the number of vehicles being manufactured to lower legacy parts demand. An exception is that demand for after-market parts may be strong if people seek to maintain their old vehicles longer, which could help some companies continue manufacturing parts for person-driven vehicles for a considerable time.

The impact on Tennessee employment depends on continued development of improved manufacturing processes, how many AVs are ultimately demanded and where vehicle assembly and parts manufacturing occur. Tennessee will fare better than average to the extent that many component parts for AVs are manufactured in the state and the state becomes an assembler of AVs, but manufacturing employment is likely to fall over the next several decades. Technology could also automate a number of tasks performed by workers and further alter employment in the manufacturing industries.

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[23] See Goolsbee (2018) for discussion of some reasons why the transition could be slow.
[24] Chris Pauly, HDR, Connected and Autonomous Vehicles, Power Point, November 13, 2018.
[25] Vehicle sales reductions have been even greater in Europe.
[26] Erik Meyhofer, UBER CEO of Advanced Technology Group, speaking on CNBC Squawk Box June 12, 2019, said that Uber expects to have AVs without safety drivers operating on the streets of 5 to 6 cities in 2020.

Vehicle Support Industries

Employment will be impacted differently across the many vehicle support industries. The concern is that demand for many support services will ultimately be eliminated or significantly reduced. Demand for some repair industries may expand for a number of years as owners maintain existing vehicles rather than purchase new. On the other hand, fewer accidents will eliminate much of the need for repair. Many other support industries, such as new vehicle dealers, may see relatively quick demise as vehicles are purchased in fleets and sales of new vehicles to individuals plummet. Of course, new car dealers and other affected firms will try to remain profitable. For example, new car dealers could focus on more repairs and used car sales. Other industries, such as finance, insurance, gas stations and so forth, will experience slow demise as fleet-owned electric AVs begin to dominate and demand for these services dissipates. Profits in these industries will fall as they become more competitive and this will cause less efficient firms to close first. Falling access to support services could ultimately hasten the movement to AVs. Overall, almost all employment in existing vehicle support industries and occupations will be eliminated. Of course, AV support positions will develop, but there may be fewer as mobility companies are likely to be vertically integrated rather than operating through a large number of small businesses.

Vehicle Intensive-Use Occupations

Some vehicle intensive-use occupations are likely to see the largest and, in many cases, fastest job losses. Further, these occupations are affected by elimination of need for a driver rather than specific characteristics of the vehicles, such as whether they are electric and how many are needed. AVs alone can dramatically impact the tasks performed by these workers. As noted above, this category includes motor vehicle operators and other on-the-job drivers. Motor vehicle operators, such as taxi drivers, rideshare drivers, and truck drivers, may see quick job losses as AVs replace 100 percent of the tasks performed by these workers. On the other hand, Uber (2018) argues that truck driving will be altered as an occupation but there may be no near-term job losses. The expectation is that AVs will do long distance driving but that people will be required to bring the truckloads into cities and to their specific destinations meaning many drivers will remain necessary.[27] Uber also believes that the cost reduction from using AVs for long distance hauls could result in more goods transported by truck and could increase the demand for local haul drivers sufficiently to offset the decline in long-distance drivers. Enough additional short distance trips to increase the total number of drivers seems unlikely to us so we expect the number of truck drivers to decline. Further, Uber believes that people will at least initially take shorter, simpler rides in AVs while riders will want drivers for longer, more complicated trips. The result is that demand for some drivers will remain for a while. More broadly, we anticipate very large job losses among motor vehicle rider occupations as the tasks are performed by AVs.

Other on-the-job drivers usually have additional roles besides driving, such as occurs with delivery

[27] Acemoglu and Restrepo (2019) describe how automation replaces certain tasks previously performed by workers (termed the displacement effect) but has a productivity effect where labor is more productive resulting in an increased demand for labor. The overall demand for workers rises only if the productivity effect exceeds the displacement effect.

workers, ambulance drivers, and plumbers. AVs will automate some tasks and thereby make the workers more productive and lower the cost of providing the services. The net effect on employment depends on whether the demand for these services rises fast enough to offset the greater productivity of the workers; if not, employment will decline.[28] Further, as noted for trucks, related AI may result in other technologies performing tasks currently done by people. For example, FedEx's pilot test of BOTs for localized delivery automates tasks formerly performed by people and together with AVs helps ease the last mile problem for delivery. In this context, AVs could drive to an area where a BOT makes a delivery, so people are no longer part of the process. In sum, we cannot be precise about the aggregate potential for job losses, but many drivers could be replaced as mobility and other AI based automation are linked together.

Many public sector workers are very intensive users of vehicles, such as most first responders, refuse collectors, public transit workers and so forth. Many of the tasks performed by these workers appear to be candidates for automation with AVs. Again, the net effect on employment depends on whether more services are demanded as the production costs fall with automation – a sufficient increase in demand could result in the same or an even greater number of workers though this seems unlikely. In any event, public sector employment will diminish more slowly if policymakers are reticent to replace workers with AVs in order to limit the transition effects on people. Of course, this simply means that the public sector is not taking advantage of the potential costs savings that could be reaped from automation. Ultimately, many public sector positions are at risk.

TAX REVENUE EFFECTS

AVs can affect tax revenues both directly and indirectly. Direct effects refer to the revenue impacts arising from taxes imposed on transportation-related activity. Direct taxes in Tennessee include:

- Gasoline Tax
- Motor Fuel Tax
- Gasoline Inspection Tax
- Motor Vehicle Registration Tax
- Motor Vehicle Title Fees
- Electric Vehicle Fee
- Sales Tax on Motor Vehicle Sales
- Auto Rental Surcharge
- Tire Tax
- Automotive Oil Fee
- Sales Tax (sales tax on selected vehicle services, including washing and waxing, road service and towing, auto services, parking lots, rustproofing, and repair materials)

[28] Acemoglu and Restrepo (2019) find that automation has replaced workers on net during the past 30 years, but tended to increase workers in the previous 40 years. AVs will in aggregate replace vehicle intensive-use workers if these occupations are similar to the average effects of technologies developed in recent decades.

Combined, these revenue sources collected $2.3 billion in Fiscal 2017-18 not including sales taxes on selected services (Table 2), and represented 16.0 percent of the $14.5 billion in tax revenues collected during that year (Figure 8). Tax revenues are directly linked to the sale of fuel (Gasoline, Motor Fuel, and Gasoline Inspection taxes), the vehicle stock (Motor Vehicle Registration, Motor Vehicle Title, and Electric Vehicle Fees), the sale of vehicles (Sales Tax), plus a few smaller sources. Thus, Tennessee taxes many different components of the traditional transportation system. This structure was designed to tax large numbers of internal combustion engine vehicles and the use of fossil fuel and does not anticipate the development of electric AVs. Introduction of electric AVs could decrease nearly all of these tax bases.

Table 2. Tennessee Motor-Vehicle Related Tax Revenue, FY2018

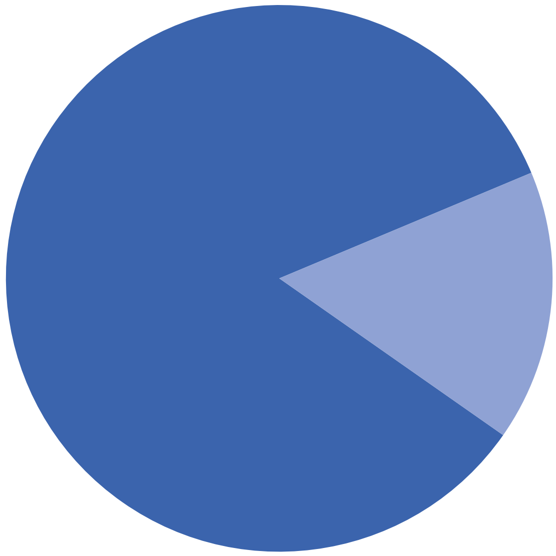
Source of Revenue		Actual Revenue
Gasoline Tax		807,686,700
Motor Fuel Tax		222,690,400
Gasoline Inspection Tax		68,964,800
Motor Vehicle Registration Tax*		327,417,400
Motor Vehicle Title Fees		25,194,900
Motor Vehicle Sales Tax[a]		849,721,456
Motor Vehicle Dealers, New and Used	*662,618,118*	
Motor Vehicle Dealers, Used Car	*187,103,338*	
Privilege Tax (motor-vehicle related)[a]		19,858,035
Auto Rental Surcharge	*12,451,228*	
Tire Tax	*6,577,888*	
Used Oil	*828,919*	
Total Motor-Vehicle Related Revenue		**2,321,533,690**

*includes Electric Vehicle Fees

a. July 2017–June 2018 summary, Tennessee Department of Revenue, *Revenue Collections*, June 2018.

Source: State of Tennessee, *The Budget, Fiscal Year 2019–2020*.

Figure 8. Tennessee Sources of Revenue, FY2018



Source: State of Tennessee, *The Budget, Fiscal Year 2019–2020*; and Tennessee Department of Revenue, *Revenue Collections*, June 2018.

AVs can be expected to reduce revenues as electric vehicles replace fossil fuel powered vehicles. Ultimately, there could be no fuel tax revenue when all vehicles are electric. The electric vehicle fee rises with the number of electric vehicles and replaces some of the revenue loss, but on net revenue will fall. The electric vehicle fee was initially set at about two-thirds of the expected fuel tax revenue for a vehicle driven an average amount. The proportion of replaced revenues will be even smaller for shared vehicles that are driven much more intensively than individually owned and driven vehicles. Some offsetting additional utility or TVA-shared revenues might result from electric power generation needed to charge vehicles.

Taxes on the vehicle stock and vehicle sales could decline as fewer AVs are necessary to replace the internal combustion engine stock. The precise proportions are estimated at this point, but the calculations above suggest that the stock of AVs would be about one-half as large as the current vehicle stock. This would result in one-half as much tax revenues on the sale and registration of vehicles, absent any policy change. The revenue loss is smaller as more AVs are required to meet future demands or if AVs are more expensive than current vehicles and the sales tax revenues per vehicle is larger. Sales taxes on vehicle services will also decline with fewer vehicles. Further, no sales tax is imposed if otherwise taxable services are delivered within the fleet company, which may occur for car washes, repairs, and some other support services. Also, no drivers' license fees would be collected with AVs. The auto rental surcharge could be eliminated unless AVs are determined to fit within current definitions of rentals. Presumably, traffic fines will also go away.

The rate of AV adoption helps determine the pace of revenue loss, though the total extent of the revenue loss is ultimately determined by (1) the replacement of internal combustion engine vehicles with electric vehicles (2) the number of vehicles required to meet demand and (3) Tennessee's tax structure. A revenue loss estimate (Fox, 2020) concluded that Tennessee could lose over 60 percent of its motor vehicle revenues when AVs have been fully adopted and if the vehicle stock is cut in half. This would represent a loss of about 8.5 percent of total Tennessee tax revenues, with vehicle taxes representing about 16 percent of total taxes.[29] Taxes will still be collected from vehicle registrations, sales taxes on vehicle transactions (though presumably based on many fewer vehicles), and electric vehicle fees. Tire taxes will also continue to be collected, and depending on the type of tires used in the future, the amount could rise if VMT per person goes up.

The revenue loss by 2040 would be much smaller if the adoption rate is modest (perhaps 30 or more years for full AV adoption, starting in 2025) and if say 60 percent as many vehicles are needed. About 4 percent of total tax revenues would be lost by 2040 if these slower-paced assumptions about AVs are more appropriate. But, the slower adoption rate does not lessen the ultimate reduction in tax revenues.

Tennessee tax revenues will also be indirectly affected as economic activity in Tennessee diminishes from the employment losses described above. Essentially every tax is linked to some type of economic activity and could fall as the state's economy transitions towards AVs. For example, sales tax revenues from consumer spending could be lowered as workers have less income and corporate excise tax revenues could fall if firms earn lower profits in Tennessee. Some or all of these revenue losses can be replaced by new economic activity related to AVs or other changes in the economy. Further, people could spend their cost savings from mobility on other goods and services, and this could lead to more sales taxable transactions. There is no tractable way to estimate the amount of revenue loss, but it is reasonable to expect large transitions given the large share of employment linked to transportation.

Estimates of effects on tax revenues assume that no policy changes occur during intervening years. We advocate for the state to make appropriate changes to level the playing field between different means of mobility and to ensure that revenues are sufficient to meet infrastructure and other needs. Unbundling of mobility will be facilitated if the tax (and regulatory) structure can be adjusted to treat all mobility the same. Such policy change will allow the economy and mobility to develop more efficiently and will help maintain tax revenues. The tax revenue loss estimates should be seen as the consequences of no change rather than the outcome actually anticipated since appropriate policy changes can lessen the losses.

We do not examine effects of AVs on state and local government expenditures, though they will certainly be affected as well. Expenditures linked to transportation could be lowered in some areas, such as reduced highway patrol. But the net effect on transportation access costs depends on infrastructure needs and operational costs, such as monitoring and regulating AVs. More broadly, AVs offer the opportunity to reduce costs of delivering many state and local government public services, including transporting school children, collecting solid waste, delivering fire protection,

[29] The estimate adjusts for the slower growth in vehicle related taxes relative to total taxes over time, so that the relative loss in revenues is somewhat lower by 2040 than it would be today.

transporting public officials in pursuit of their duties, and so forth. Thus, the effect on the net fiscal position of governments (measured as the change in revenues minus change in expenditures) depends on a wide range of impacts that could influence every part of state and local governments, and the key observation is that the net fiscal effects could be widely different and potentially smaller than the revenue losses described here.

POLICY IMPLICATIONS

New technologies are changing Tennessee's business environment and workforce needs at an unprecedented pace. AVs are perhaps the prime example of disruptions in Tennessee, impacting up to one-sixth of workers, but are only one area where AI is altering the goods and services we consume and the way they are produced and received. We expect a significant share of Tennessee vehicle-related employment to be lost or the tasks performed by the workers to be changed significantly, but it is important to remember that new vehicle-related jobs will be created, as will other jobs in the economy. Tennessee must transform aggressively if it is to be an economic leader as these many changes occur.

We believe the AV era is rapidly approaching and the main question is how fast adoption will occur, not whether AVs will happen. Tennessee still has the opportunity to stay ahead of the dramatic policy and economic transitions that have already started and will continue over the next several decades as mobility is unbundled.

One step is for Tennessee to track employment and the vehicle stock to find early signals that the economy is being impacted by AVs. For example, Table 3 could be extended year by year to identify where and the extent to which employment is being affected. No change has occurred as yet. As seen in the Table, employment in the key industries is still rising and the vehicle related sector looks very robust, but we anticipate relatively fast transitions once they begin. The state will be able to see effects on the various employment sectors as AVs begin to develop, and to some extent, as electric cars grow in popularity. Tennessee has few electric vehicles as of now, though the stock rose 20 percent in 2018. Tennessee has about 70,000 more hybrid vehicles, but combined these alternative fuel vehicles are only scratching the surface. Hybrid vehicles still rely on motor fuel but their high miles per gallon mean slow erosion of the fuel tax even before electric vehicles eliminate the tax revenues. We expect much faster adoption of electric vehicles in the future, particularly when the vehicles are fleet owned. Furthermore, Tennessee will most likely experience the economic and employment impact of electric and autonomous vehicle at a more rapid rate than Tennessee's electric vehicle stock increases.

Table 3. Tennessee Vehicle Related Indicators

MEASURES TO BE TRACKED	2015	2016	2017	2018	2025
Vehicle-Related Employment [a,b]					
Vehicle Manufacturing	**64,120**	**69,613**	**72,507**	**72,132**	
Assembly	19,049	20,944	22,013	21,528	
Parts Manufacturing	45,071	48,669	50,494	50,604	
Vehicle Support [c]	**112,126**	**115,264**	**118,993**	**121,481**	
Retail	75,036	76,240	78,227	79,600	
Insurance	14,348	14,992	15,383	15,879	
Services	22,742	24,032	25,383	26,002	
Vehicle-Intensive-Use [d]	**281,146**	**285,879**	**291,000**	**–**	
Motor Vehicle Operators	100,660	102,620	102,510	–	
Other On-the-Job Drivers	180,486	183,259	188,490	–	
Total Motor Vehicle Registrations [e]	**5,612,123**	**5,709,923**	**5,800,489**	**–**	
Non-Electric Vehicles	–	–	5,729,518	–	
Hybrid Vehicles (HEV and PHEV)	–	–	67,933	73,769	
Electric Vehicles (EVs)	–	–	3,038	3,634	

Notes: Employment estimates may be unavailable for a variety of reasons including failure to obtain data from the entire sample, the inability/unwillingness of respondents to provide data, etc. For a comprehensive explanation, please see BLS web page https://www.bls.gov/oes/2018/may/oes_research_estimates.htm.

a. Employment by industry data are private-industry workers covered by the unemployment insurance program.
b. Occupations are based on the Office of Management and Budget's 2010 Standard Occupational Classification (SOC) system.
c. Retail includes motor vehicle and parts dealers, auto dealers, auto parts accessories and tire stores, convenience stores, gasoline stations. Insurance includes direct insurers (except life and health) and other insurance related activities. Services includes auto equipment rental and leasing, auto repair and maintenance, parking lots and garages.
d. Employment by occupation.
e. Total motor vehicle registrations include automobiles, buses, trucks, and motorcycles, all ownership categories (private, public, and commercial).

Source: Bureau of Labor Statistics, *Quarterly Census of Employment and Wages: Tennessee; BLS, Occupational Employment Statistics; State of Tennessee, Department of Revenue, direct correspondence*; and U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*.

The state can develop appropriate policies now without a high sense of urgency, but with the intent of getting ahead of the curve. Enacting policy changes relatively soon benefits Tennessee in several ways. First, this gives the state a chance to be a leader rather than a follower in a vitally important industry. Appropriate policy will increase Tennessee's chance to be a place where related industries want to work and grow. Second, tax revenue needed to enhance the mobility infrastructure can be maintained more effectively. Third, failure to evolve policy relatively soon will result in the state being very unevenly affected and in many cases to the disadvantage of rural Tennessee. Urban residents and businesses may feel the benefits of AVs first and could pay less taxes, at least in the beginning. For example, tax policy that continues to tax fossil fuel likely leaves many rural residents and businesses paying an uneven share of the burden because they will change to AVs more slowly. Urban dwellers will shift more rapidly to shared electric AVs that will be taxed much less with the existing structure. Similarly, infrastructure development will probably be very uneven – again probably benefitting urban residents more. Employment losses may not be concentrated in rural places, but finding alternative jobs may be harder when they occur there. Fourth, policy change will become more difficult to enact as entrenched interests grow. Political views and self-serving positions will become hardened and make it more difficult to develop policies that are best for the state. Fifth, the industry can develop more efficiently if business and consumers know the tax and regulatory structures that they will confront.

The impacts of AVs alone cross many spheres of Tennessee state government policy. Some key areas where Tennessee should decide on the best policies include (but are not limited to):

Regulatory Policy. Tennessee should continue addressing appropriate regulations for allowing unbundled mobility in the state. AVs will be a key component of mobility, but shared bicycles and scooters, new and expanded delivery mechanisms and others are likely to be part of an integrated system of mobility. The state does not want to be unduly permissive, but may want to be a leader in allowing new technologies so that businesses see Tennessee as a good place to develop, manufacture, and benefit from evolving mobility.[30]

Worker Transition. As discussed in the report, many workers will see their tasks, jobs, and occupations radically altered or even eliminated. The very rapid pace of change is the uniquely different element of this technology induced employment transition and will try both the education system and workers' abilities to move geographically and across industries and occupations. Many of those working in jobs at risk from AVs are older and have lower education and skill, further complicating the challenge of smoothing the transition. Workforce education and retraining is absolutely essential for workers whose jobs are affected and the options will need to evolve quickly as technologies are changing rapidly. Tennessee may want to continue building on programs, such as exist in the Tennessee Department of Labor and Workforce Development, to facilitate movement across jobs, careers and occupations.

Workforce Preparation. Education and training are the most important ways that Tennessee can prepare its workforce to be entrepreneurial and to meet the business needs of the next decades. Admittedly, this is a challenging time to know precisely what the workforce demands will be, but it is the time to have serious discussions about how best to proceed and how to ensure that high school and post-secondary education head in a direction that is consistent with the changing

[30] See https://www.al.com/news/anniston-gadsden/2019/03/how-the-alabama-legislature-is-preparing-for-self-driving-cars.html for discussion of how Alabama is considering new regulations. Another example is Chandler, AZ, which has reduced its minimum parking requirements for new developments in anticipation of AVs. See https://www.lincolninst.edu/publications/articles/driverless-ed.

workforce demands. THEC, Community Colleges, TCATs, and universities need to continue preparing for the changing labor force demands, both in terms of how education is delivered and the types of training and education made available. THEC, for example, formed a taskforce on the "Tennessee Future of Work Taskforce." It is important to remember that the education supply chain for younger Tennesseans is relatively long. AVs are likely to be a reality on our streets by the time today's high school sophomores are finishing two to four years of post-high school education. In this sense, the timing is urgent because we must be preparing now.

Infrastructure. Infrastructure needs will ultimately be different in the unbundled mobility/AV era as we depend on ever higher speed information access, smart signaling, ease of charging and many other elements that facilitate mobility. At the same time, traditional infrastructure like roads and bridges is needed. Given the inflexible nature of some infrastructure, the state must be careful to develop new and improved infrastructure that promotes mobility with AVs, and does not simply look backwards to traditional styles of infrastructure.[31]

Tax Policy. Tennessee, like all other states, has created a tax system that is highly dependent on the number of vehicles and fossil fuel in an era where these tax bases will play declining roles. Tennessee's electric vehicle fee is a step towards a more balanced revenue system, but still leaves internal combustion engine vehicles paying a relatively large share of the budget. The likelihood of slower adoption of AVs in rural places means residents of these areas will pay a larger share of the tax burden without modifications in the structure, both because they will own and use more vehicles per person than urban dwellers and because they will be more likely to continue driving internal combustion engine vehicles. The tax system could be modernized to focus on mobility rather than on a particular way of moving goods and people through and around the state in order to share the cost across all forms of mobility. The system could also be designed so that revenue growth creates the potential to finance key investments that facilitate the evolving forms of mobility.

Public Service Delivery. AVs offer the opportunity to transform how many public services are delivered. Effects on Tennessee employment and delivery costs depend on the willingness and pace at which governments are willing to use more AI and AVs to lower costs and improve service delivery, even if this requires eliminating some jobs. Tennessee can be planning now for how to implement new technologies and automation.

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[31] The potential for narrower lanes, AV exclusive lanes, and more pick up zones are among the many issues to consider. See https://www.lincolninst.edu/publications/articles/driverless-ed.

BIBLIOGRAPHY

Acemoglu, Daron and Pascual Restrepo, "Automation and New Tasks: How Technology Displaces and Reinstates Labor," *Journal of Economic Perspectives,* 33: 3-30, Spring 2019.

Bureau of Labor Statistics. (2019) *Quarterly Census of Employment and Wages 2007-2017* [Dataset] Retrieved from: https://www.bls.gov/cew/

Clements, Lewis M. and Kara M. Kockelman. "Economic Effects of Automated Vehicles," *Transportation Research Record* No. 2602, 2017.

Davis, S.C., Williams, S.E. and Boundy, R.G. 2018. *Transportation Energy Data Book Edition 36*; ORNL 5198; Oak Ridge National Laboratory: Oak Ridge, TN, 2017

FOCUS Online. (2016, September 01). Das Elektroauto vernichtet Arbeitsplätze. Retrieved August 15, 2018, from https://www.focus.de/auto/elektroauto/auto-vw-personalchef-werk-salzgitter-braucht-neue-aufgaben_id_5930673.html

Fox, William F. "The Effect of Autonomous Vehicles on State Tax Revenues," *National Tax Journal* forthcoming, March 2020.

Goolsbee, Austan. "Public Policy in an AI Economy," paper prepared for the NBER Conference on Artificial Intelligence.

Graehler, Michael, Richard Alexander Mucci, and Gregory D. Erhardt, "Understanding the Recent Transit Ridership Decline in Major U.S. Cities: Service Cuts of Emerging Modes," Presented at the 98th Annual Meeting of the Transportation Research Board, 2019.

Manyika, James, et al., "Jobs Lost, Jobs Gained: What the future of Work will Mean for Jobs, Skill, and Wages," McKinsey & Company, November, 2017.

Mark Muro, et.al, Brookings Institute. *Automation and Artificial Intelligence: How Machines Are Affecting People and Places.* January 2019.

Mosquet, X., Zablit, H., Dinger, A., Xu, G., Andersen, M., & Tominaga, K. (2018, January 11). "The Electric Car Tipping Point Future of Powertrains for Owned and Shared Mobility." Retrieved August 14, 2018, from https://www.bcg.com/en-us/publications/2018/electric-car-tipping-point.aspx

Ratner, Stephen, "Taxation of Autonomous Vehicles in Cities and States," Comment, *Tax Lawyer*, Vol 71, No. 4, November 13, 2018.

RethinkX, "Rethinking Transportation 2020-2030," May 2017.

Society of Automotive Engineers, "Automated D,"SAE J3016, 2014.

S&P Global, "The Road Ahead for Autonomous Vehicles," May 14, 2018.

Tennessee Department of Economic and Community Development (2016). *The Tennessee Automotive Industry*.

Tennessee Department of Economic and Community Development (2019). *Masters of Automotive Manufacturing* [online] https://tnecd.com/industries/automotive/.

Uber, "The Future of Trucking," February 1, 2018. https://medium.com/@UberATG/the-future-of-trucking-b3d2ea0d2db9.

APPENDIX A

Vehicle-Related Employment by Industry: Tennessee and the U.S.

Industry	Employment 2017	CAGR (%) 2007-17
TENNESSEE		
Vehicle Manufacturing		
NAICS 32621 Tire mfg	3,957	-4.6
NAICS 3361 Motor vehicle mfg	19,899	4.7
NAICS 3362 Motor vehicle body & trailer mfg	2,114	-0.9
NAICS 3363 Motor vehicle parts mfg	46,537	2.3
Subtotal: Vehicle Manufacturing	*72,507*	*2.2*
Vehicle Support		
NAICS 4231 Motor vehicle & parts	10,235	0.3
NAICS 4411 Automobile dealers	27,548	0.6
NAICS 4413 Auto parts accessories & tire stores	16,135	1.5
NAICS 44512 Convenience stores	1,203	2.9
NAICS 447 Gasoline stations	23,106	-0.3
NAICS 52412 Direct insurers except life & health	7,331	-1.9
NAICS 52429 Other insurance related activities	8,052	4.9
NAICS 5321 Auto equipment rental & leasing	6,731	6.8
NAICS 8111 Auto repair & maintenance	16,143	0.7
NAICS 81293 Parking lots & garages	2,509	2.4
Subtotal: Vehicle Support	*118,993*	*0.9*
U.S.		
Vehicle Manufacturing		
NAICS 32621 Tire mfg	55,808	-0.6
NAICS 3361 Motor vehicle mfg	223,097	0.0
NAICS 3362 Motor vehicle body & trailer mfg	155,870	-0.6
NAICS 3363 Motor vehicle parts mfg	588,899	-0.3
Subtotal: Vehicle Manufacturing	*1,023,674*	*-0.3*
Vehicle Support		
NAICS 4231 Motor vehicle & parts	334,967	-0.4
NAICS 4411 Automobile dealers	1,291,109	0.4
NAICS 4413 Auto parts accessories & tire stores	553,445	1.1
NAICS 44512 Convenience stores	161,819	1.3
NAICS 447 Gasoline stations	931,565	0.8
NAICS 52412 Direct insurers except life & health	544,305	-0.7
NAICS 52429 Other insurance related activities	332,934	3.7
NAICS 5321 Auto equipment rental & leasing	212,856	0.9
NAICS 8111 Auto repair & maintenance	921,695	0.4
NAICS 81293 Parking lots & garages	140,794	2.4
Subtotal: Vehicle Support	*5,425,489*	*0.7*

Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

APPENDIX B

Employment by Vehicle Intensive-Use Occupation: Tennessee, Selected Years

Occupations are based on the Office of Management and Budget's 2010 Standard Occupational Classification (SOC) system.

a. employment estimates not available

Note: Employment estimates may be unavailable for a variety of reasons including failure to obtain data from the entire sample, the inability/unwillingness of respondents to provide data, etc. For a comprehensive explanation, please see BLS web page https://www.bls.gov/oes/2018/may/oes_research_estimates.htm.

Source: Bureau of Labor Statistics, *Occupational Employment Statistics.*

									Percentage 2007-2017	
Occupation	**2007**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Change**	**CAGR**
Motor Vehicle Operators	**105,120**	**98,400**	**97,570**	**96,640**	**96170[a]**	**100,660**	**102,620**	**102,510**	**-2.50%**	**-0.30%**
Ambulance Drivers & Attendants, Except EMTs	670	150	270	340	(a)	180	150	110	-83.60%	-16.50%
Bus Drivers, Transit & Intercity	3,140	2,520	2,510	2,900	2,730	2,700	2,540	2,560	-18.50%	-2%
Bus Drivers, School or Special Client	9,230	9,430	10,060	9,820	9,810	10,240	11,190	10,380	12.50%	1.20%
Driver/Sales Workers	9,800	12,160	9,270	7,390	7,830	8,550	9,060	8,100	-17.30%	-1.90%
Heavy & Tractor-Trailer Truck Drivers	60,730	54,640	53,470	49,020	48,610	52,580	58,120	60,350	-0.60%	-0.10%
Light Truck or Delivery Services Drivers	19,810	17,730	20,210	25,330	25,010	23,870	18,810	18,320	-7.50%	-0.80%
Taxi Drivers & Chauffeurs	1,740	1,770	1,780	1,840	2,180	2,540	2,750	2,690	54.60%	4.50%
Other On-the-Job Drivers	**168,100**	**171304[a]**	**173,297**	**176,623**	**177647[a]**	**180485[a]**	**183259[a]**	**188,490**	**12.10%**	**1.20%**
Total, Vehicle-Intensive Use Occupation Employment									**6.50%**	**0.60%**

Employment by Vehicle Intensive-Use Occupation in the U.S.

Source: Bureau of Labor Statistics, Occupational Employment Statistics.

	U.S.			
	Employment		Percentage	
Occupation	**2007**	**2017**	**Change**	**CAGR**
Motor Vehicle Operators	3,836,600	3,949,940	3.0%	0.3%
Ambulance Drivers & Attendants (Except EMTs)	21,520	15,310	-28.9%	-3.3%
Bus Drivers, Transit & Intercity	189,050	176,140	-6.8%	-0.7%
Bus Drivers, School or Special Client	461,590	507,340	9.9%	0.9%
Driver/Sales Workers	382,360	426,870	11.6%	1.1%
Heavy & Tractor-Trailer Truck Drivers	1,693,590	1,748,140	3.2%	0.3%
Light Truck or Delivery Services Drivers	922,900	877,670	-4.9%	-0.5%
Taxi Drivers & Chauffeurs	165,590	198,470	19.9%	1.8%
Other On-The-Job Drivers	11,077,680	12,621,240	13.9%	1.3%
Total, Vehicle Intensive-Use Occupation Employment	**14,914,280**	**16,571,180**	**11.1%**	**1.1%**

APPENDIX C

Vehicle-Intensive Occupations

SOC	OCCUPATION
11-9061	Funeral Service Managers
11-9161	Emergency Management Directors
11-9199	Managers, All Other
13-1032	Insurance Appraisers, Auto Damage
13-1041	Compliance Officers
13-1074	Farm Labor Contractors
13-2021	Appraisers and Assessors of Real Estate
17-1022	Surveyors
17-3025	Environmental Engineering Technicians
17-3027	Mechanical Engineering Technicians
17-3031	Surveying and Mapping Technicians
19-1023	Zoologists and Wildlife Biologists
19-1031	Conservation Scientists
19-1032	Foresters
19-2041	Environmental Scientists and Specialists, Including Health
19-4011	Agricultural and Food Science Technicians
19-4091	Environmental Science and Protection Technicians, Including Health
19-4092	Forensic Science Technicians
19-4093	Forest and Conservation Technicians
25-9021	Farm and Home Management Advisors
29-2041	Emergency Medical Technicians and Paramedics
33-1011	First-Line Supervisors of Correctional Officers
33-1012	First-Line Supervisors of Police and Detectives
33-1021	First-Line Supervisors of Fire Fighting and Prevention Workers
33-2011	Firefighters
33-2021	Fire Inspectors and Investigators
33-2022	Forest Fire Inspectors and Prevention Specialists
33-3012	Correctional Officers and Jailers
33-3021	Detectives and Criminal Investigators
33-3031	Fish and Game Wardens
33-3041	Parking Enforcement Workers
33-3051	Police and Sheriff's Patrol Officers
33-3052	Transit and Railroad Police
33-9011	Animal Control Workers
33-9021	Private Detectives and Investigators
33-9032	Security Guards
37-2021	Pest Control Workers
37-3012	Pesticide Handlers, Sprayers, and Applicators, Vegetation
37-3013	Tree Trimmers and Pruners
39-4011	Embalmers

Appendix C *continued*

SOC	OCCUPATION
39-4021	Funeral Attendants
39-4031	Morticians, Undertakers, and Funeral Directors
39-6011	Baggage Porters and Bellhops
39-7011	Tour Guides and Escorts
39-7012	Travel Guides
39-9011	Childcare Workers
39-9021	Personal Care Aides
41-9022	Real Estate Sales Agents
43-5021	Couriers and Messengers
43-5041	Meter Readers, Utilities
43-5052	Postal Service Mail Carriers
45-4011	Forest and Conservation Workers
45-4023	Log Graders and Scalers
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers
47-2041	Carpet Installers
47-2111	Electricians
47-2131	Insulation Workers, Floor, Ceiling, and Wall
47-2152	Plumbers, Pipefitters, and Steamfitters
47-2161	Plasterers and Stucco Masons
47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters
47-4011	Construction and Building Inspectors
47-4021	Elevator Installers and Repairers
47-4041	Hazardous Materials Removal Workers
47-4051	Highway Maintenance Workers
47-4071	Septic Tank Servicers and Sewer Pipe Cleaners
47-4091	Segmental pavers
47-4099	Construction and related workers, all other
47-5031	Explosives Workers, Ordnance Handling Experts, and Blasters
47-5081	Helpers--Extraction Workers
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers
49-2011	Computer, Automated Teller, and Office Machine Repairers
49-2021	Radio, Cellular, and Tower Equipment Installers and Repairers
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles
49-2097	Electronic Home Entertainment Equipment Installers and Repairers
49-2098	Security and Fire Alarm Systems Installers
49-3021	Automotive Body and Related Repairers
49-3022	Automotive Glass Installers and Repairers
49-3023	Automotive Service Technicians and Mechanics
49-9011	Mechanical Door Repairers
49-9012	Control and Valve Installers and Repairers, Except Mechanical Door
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers
49-9031	Home Appliance Repairers
49-9051	Electrical Power-Line Installers and Repairers

Appendix C *continued*

SOC	OCCUPATION
49-9052	Telecommunications Line Installers and Repairers
49-9063	Musical Instrument Repairers and Tuners
49-9081	Wind Turbine Service Technicians
49-9091	Coin, Vending, and Amusement Machine Servicers and Repairers
49-9092	Commercial Divers
49-9094	Locksmiths and Safe Repairers
51-8012	Power Distributors and Dispatchers
51-8092	Gas Plant Operators
51-8099	Plant and System Operators, All Other
53-6021	Parking Lot Attendants
53-6031	Automotive and Watercraft Service Attendants
53-6041	Traffic Technicians
53-6051	Transportation Inspectors
53-7071	Gas Compressor and Gas Pumping Station Operators
53-7072	Pump Operators, Except Wellhead Pumpers
53-7073	Wellhead Pumpers
53-7081	Refuse and Recyclable Material Collectors

Source: David Beede, Regina Powers, and Cassandra Ingram. Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce. (August 11, 2017). *The Employment Impact of Autonomous Vehicles* (ESA Issue Brief # 05-17).