Autonomous Vehicles and Road Usage Charge

Updated Draft Business Case for Road Usage Charge on Autonomous Vehicles

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INITIAL DRAFT	10/9/18	---
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ACRONYMS

AV	Autonomous Vehicle
AVO	Amplitude Versus Offset
BTS	Bureau of Transportation Statistics
DOT	Department of Transportation
EV	Electric Vehicle
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
MaaS	Mobility as a Service
MPG	Miles Per Gallon
MY	Model Year
NHTS	National Household Travel Survey
OEM	Original Equipment Manufacturer
RUC	Road Usage Charge
SAEV	Shared Automated Electric Vehicle
SAFE	Securing America's Future Energy
TNC	Transportation Network Company
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VIN	Vehicle Identification Number
VMT	Vehicle Miles Traveled

1 INTRODUCTION

The recent development of automated vehicle (AVs) technologies, coupled with the ongoing need to resolve deficiencies in state highway transportation funds, presents the Western Road Usage Charging Consortium (RUC West) with a unique opportunity to explore how Road Usage Charges (RUC) might be levied on AVs in the future. This document provides a business case for such a strategy.

While it is not known how or under what timeframe AVs may be introduced to the auto market, initial research has shown that AV adoption may increase Vehicle Miles Traveled (VMT), thus increasing wear and tear on the roadway. Additionally, over half of all AVs deployed are likely to be electric. As such, they will not require gasoline or diesel and will not pay any state or federal fuel taxes. Furthermore, the availability of electric vehicles (EV) and their adoption by drivers is likely to increase as electric battery technologies improve and more automobile manufacturers launch fully electric AVs. Finally, AVs are expected to be highly concentrated in urban areas, where almost 50% of trips take place. As such, they are likely to place more stress on already strained urban networks and exacerbate the existing gap in gas tax revenues relative to use of the roadway network. Therefore, a clear case exists for examining AVs as an initial target for future RUC initiatives.

The opportunity to apply RUC on AVs could provide a transportation funding shortfall solution that supports a sustainable, usage-based funding approach for maintaining critical transportation infrastructure while further educating the public on how AVs could improve lives.

This business case presents the opportunities and benefits of levying a RUC on AVs, risks associated with levying this fee, notional revenue forecasts, a proposed technical systems environment, potential impacts on operations, and potential steps that RUC West and their participating states could take to further research and initiatives for imposing a RUC on AVs. The information provided in this business case is for research purposes only and should be refined based on the unique operational and financial considerations for each RUC West state.

This business case report is outlined in the following sections:

- Section 1: Introduction
- Section 2: The Opportunity to Levy RUC on AVs
- Section 3: Benefits of this Approach
- Section 4: Associated Risks
- Section 5: Notional Revenue Forecast and Assumptions
- Section 6: Potential Technical Systems Environment
- Section 7: Operational Impacts
- Section 8: Conclusion

2 THE OPPORTUNITY TO LEVY ROAD USAGE CHARGE ON AUTONOMOUS VEHICLES

To fully assess the opportunities for levying RUC on AVs, a better understanding of the challenges facing current transportation funding sources is required. Fuel taxes, the main source of transportation funding in the US, are not sustainable in the long term. Vehicles are becoming more fuel efficient and more vehicles are being produced that run on non-taxed fuels such as electricity. AVs will exacerbate these long-term funding declines for three main reasons:

1. Mobility as a Service (MaaS) providers are expected to own a large share of the AV fleet;
2. AVs will be predominantly powered by electric engines; and
3. Increases in VMT are expected to be predominantly burdened by AVs.

The idea of using vehicles with automated driving functions continues to gain popularity amongst motorists. With increasing levels of automation, automobiles require less and less driver intervention and the opportunities for people to make their lives less hectic and more productive increase. Under an AV-oriented market, drivers can simply become passengers and use time previously spent battling congestion to be more productive at work, catch up on leisure activities, or simply relax and enjoy the world around them. This means that drivers may be less concerned about finding the quickest, least congested routes to their job, home or leisure activities and it is unknown how exactly automated vehicles will ultimately impact how, when, and where Americans drive in the long term. While there are few fully automated vehicles currently on the market, their convenience and utility may lead to high demand once they become more available.

Unfortunately, estimates as to how fast fully automated vehicles will be available on the market and the extent to which they will be purchased and used by drivers vary significantly. Depending on how AVs are defined, as well as various market assumptions, estimates of AVs as a percentage of new vehicles sales in 2030 can range from 25 percent[1] to 50 percent[2]. Furthermore, because it is difficult to predict how many AVs will be on the road and how they will be used, it is difficult to predict how they will impact the roadway system. For example, automated vehicles could lead to lower Average Vehicle Occupancy (AVO) for domestic passenger vehicles since AVs could possibly be used by multiple parties through a subscription service and would likely spend time between trips on the roadway without a passenger. A recent KPMG estimated that if AVs lower AVO to 0.95, then total Vehicle Miles Travelled by vehicles in the US could double by 2050.

(Figure 1)**.**At the same time, if ridesharing and other mobility services that incentivize carpooling can raise AVO to 2, then annual VMT could remain effectively flat through 2050 [3].

[1] Garrett, Olivier. *Forbes.*" 10 Million Self-Driving Cars Will Hit The Road By 2020 -- Here's How To Profit." 3 March 2017. https://www.forbes.com/sites/oliviergarret/2017/03/03/10-million-self-driving-cars-will-hit-the-road-by-2020-heres-how-to-profit/#6092eedf7e50. Last Accessed: 29 October 2018.

[2] Litman, Todd. *Autonomous Vehicle Implementation Predictions: Implications for Transport Planning.* Victoria Transport Policy Institute. 24 July 2018.

[3] http://www.greencarcongress.com/2015/11/20151126-kpmg.html

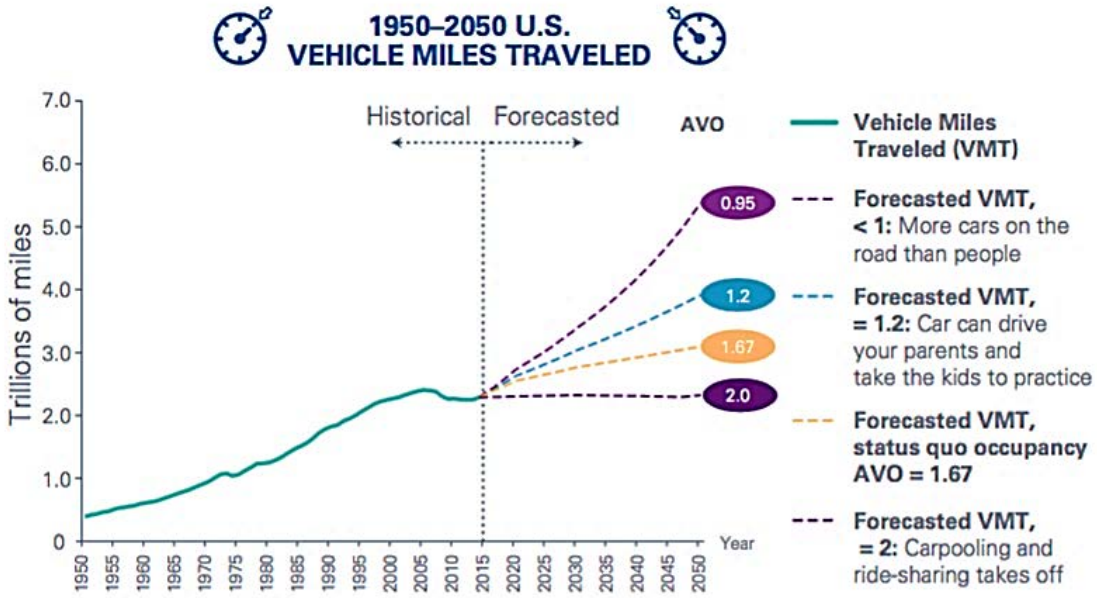

Figure 1: **VMT Forecast to 2050**[4]

In addition to changing use patterns, AVs are also likely to further impact the already changing nature of vehicle ownership. Drivers have an ever-growing number of alternatives to owning their own vehicle. An emerging group of MaaS companies provide an array of services that allow transportation system users to travel without their own vehicle, often through the use of shared vehicles and smartphone applications. Transportation Network Companies (TNCs), in particular, are looking to augment their existing fleets and regional markets with AVs and are creating a fleet of Shared Automated Electric Vehicles (SAEVs) which would provide transportation on-demand to their subscribers without the need for a driver. Such a transition could drastically change ownership models for private vehicles, as many consumers may choose to address their transportation needs through a MaaS provider, rather than purchase a vehicle that is only used a small portion of the day. Some predict that MaaS will account for 35 percent of all personal mobility by 2030 and perhaps as much as 90 percent by 2040, which poses a direct threat to traditional notions of vehicle ownership.[5] This shift in ownership models poses a particular opportunity for RUC implementation. If users of these services are already familiar and comfortable with paying for travel on a trip-by-trip basis, a RUC on shared mobility services could be met with more public acceptable than if applied initially on personally owned vehicles.

MaaS providers are also exploring ways to reduce operational costs, mainly through electrifying their fleets and eliminating the need to purchase fuel for their vehicles. With fewer engine components,

[4] http://www.greencarcongress.com/2015/11/20151126-kpmg.html
[5] Goodall, Fishman, Bornstein, and Bonthron, The rise of mobility as a service, 2017, Deloitte Institute

electric vehicles have lower operating and maintenance costs and are therefore desirable to autonomous fleet owners.[6] Research conducted by Securing America's Future Energy (SAFE), a leading conglomeration of military and business leaders focused on reducing dependence on oil, found that AVs being built and tested today disproportionately use electric or hybrid powertrains (Figure 2).[7] This percentage is only expected to increase as battery and vehicle technologies improve and automobile manufacturers find more and more ways to reduce dependencies on fossil fuels.

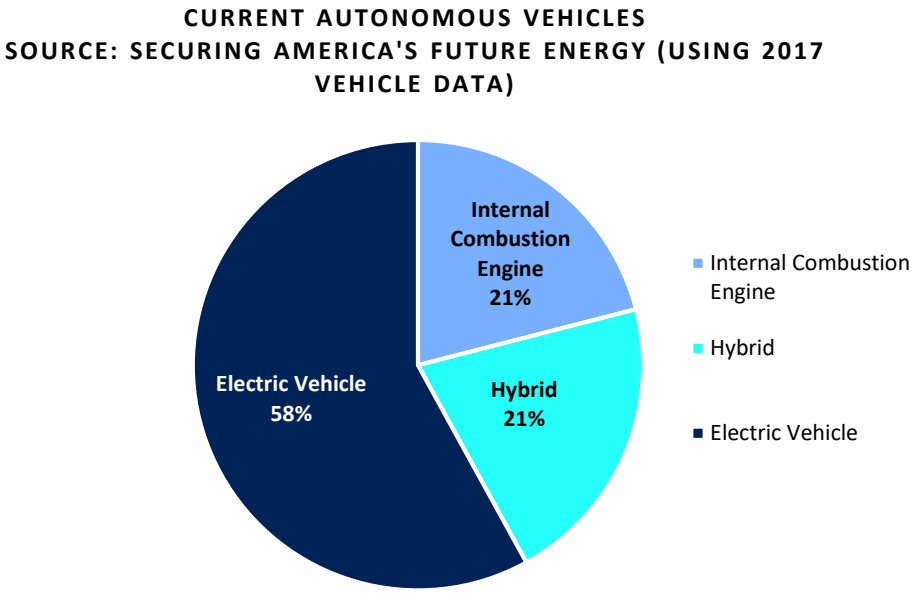

Figure 2: Current Autonomous Vehicle Powertrain Composition

In conclusion, AVs are anticipated to be a significant contributor to VMT over time and VMT increases due to AV vehicles may be exacerbated by trends in the shared economy and MaaS. Considering the observation that AV systems are expected to be dominated by electric propulsion systems and will not contribute to fuel tax revenues, there is a significant opportunity to levy a per-mile charge on AVs. The benefits, risks, and other considerations with such an approach are presented in subsequent sections of this document.

[6] https://insideevs.com/electric-cars-cost-less-ice/
[7] https://secureenergy.org/press/safe-analysis-shows-80-percent-light-duty-autonomous-vehicles-use-alternative-fuel-powertrains/

3 BENEFITS OF THIS APPROACH

There are several benefits that can be gained from levying a RUC on AVs. Some of the benefits discussed in this section include:

- Provide a more sustainable transportation funding source with improved revenues
- Privacy concerns could be mitigated through subscriptions and fleet-based services
- May promote improved public acceptance and familiarity with RUC
- Enhanced information for capital project planning
- Facilitate real-time transportation network system management and performance monitoring

3.1 PROVIDE A MORE SUSTAINABLE TRANSPORTATION FUNDING SOURCE WITH IMPROVED REVENUES

Previous studies have shown that the current gas tax model is no longer sustainable as vehicles continue to become more fuel efficient (Figure 3), however, levying a RUC on AVs could increase transportation revenues and provide a direct link to actual road usage. Given that 58 percent of AV powertrains are likely to be electric powered (Figure 2) and not pay any fuel taxes, there is potentially a significant amount of revenue that will never be realized without some sort of RUC on all AVs. Policy considerations may be needed for states that already impose a vehicle registration royalty on EVs, as levying a RUC in those cases could constitute double taxation. However, at a minimum, imposing a per-mile charge on AVs should improve overall transportation revenues. A notional forecast of revenues that could be recognized is provided in Section 5 of this report.

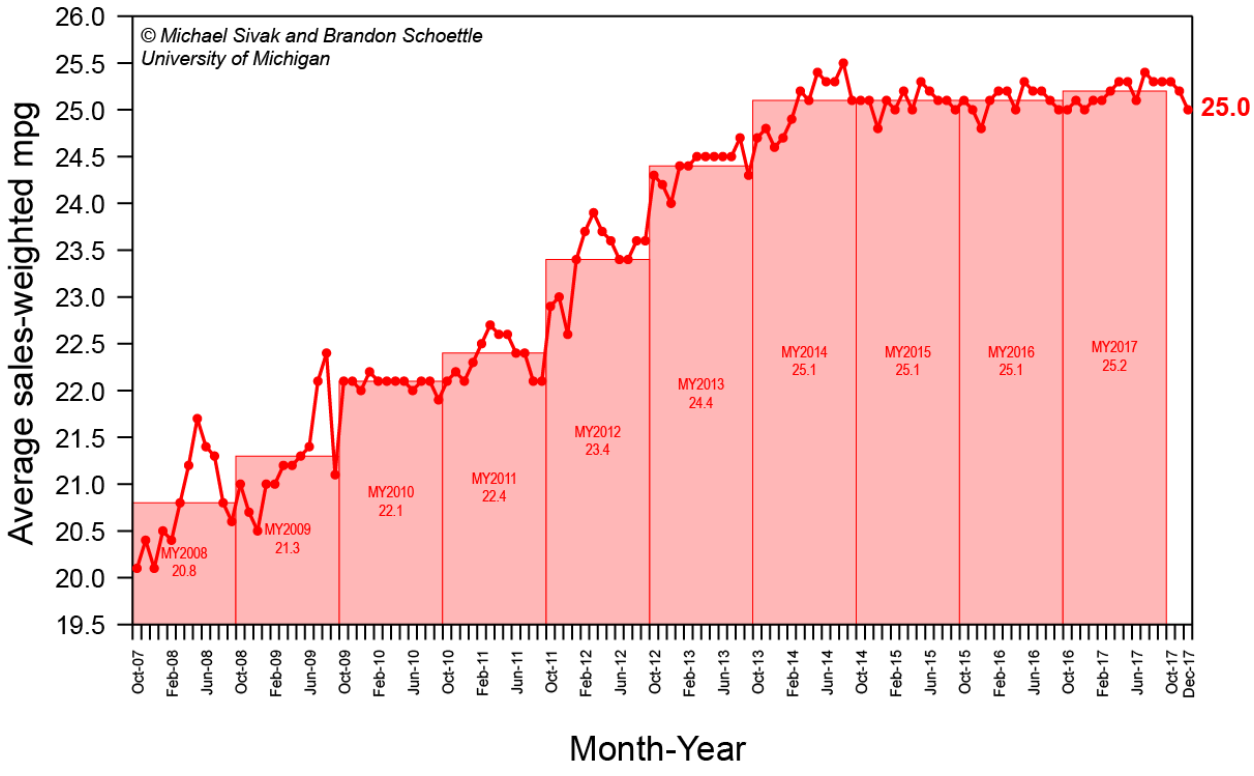

Figure 3: Average Vehicle Fuel Economy - (2007 – 2017)[8]

These additional revenues could also allow states to enhance their existing infrastructure to be more accommodating to AVs. Currently, a large amount of AV testing is occurring in the southwest where the climate is milder, the roadway network is more spread out, and roadways are better equipped with basic infrastructure such as street lighting and good signage as well as modern Intelligent Transportation Systems (ITS) technologies. States can do very little about their climate, but they can make investments in their current infrastructure that make deployment of AVs more feasible. Such enhancements include, but are not limited to: reflective striping, improved wireless communications, better sensors, cameras, and dedicated AV lanes. All of these enhancements can be procured using new RUC revenues which, in turn, could make certain areas more appealing to AV deployments. Encouraging AV deployment, in this case, would generate significantly more revenue.

3.2 Privacy Concerns Could be Mitigated Through Subscriptions and Fleet-based Services

Privacy has been shown to be one of the key public concerns with RUC programs nationwide. Drivers have expressed concern that location-based RUC systems would give government agency's the ability to track where and when they travel, perhaps in real time. However, the growth in ride hailing, ride sharing, and fleet-based mobility-as-a-service (MaaS) applications may provide an opportunity to levy a RUC that minimizes these concerns. In regards to MaaS, drivers have already shown a willingness to give up significant privacy protections and location data for the benefit of mobility on demand without having to own a vehicle. Motorists subscribe to a MaaS provider and are subject to the terms and conditions from that provider, including data reuse and privacy protection. Building off of this current billing model, a RUC could similarly be collected as an additional fee on each transaction. As with current RUC programs, states would only receive sanitized, aggregated data from the MaaS provider and would not identify individual users. In fact, no information on the MaaS user is needed; only an identifier for the vehicle they were traveling in. AVs would be registered to the MaaS provider and the state could not tie a vehicle registration to a particular motorist. This provides additional separation between the state and the motorist which in turn, could help further protect motorist privacy. Some states may choose to provide even more protection of driver privacy by regulating they type of data that can be collected by a service provider, how that data can be used, and the required notification that MaaS users must receive regarding use of their activity data. California, for example, recently passed the California Consumer Privacy Act of 2018 that will:[9]

- Grant consumer the right to request businesses disclose the categories and specific pieces of personal information that it collects about the consumer, the categories of sources from which that information is collected, the business purposes for collecting or selling the information, and the categories of 3rd parties with which the information is shared;
- Require businesses to make disclosures about the information and the purposes for which data is used;

[8] http://www.umich.edu/~umtriswt/EDI_sales-weighted-CAFE.html

[9] *California Consumer Privacy Act of 2018*, Assembly Bill No. 375. California State Assembly (2017-2018).

- Grant consumers the right to request their personal information be deleted and require businesses to delete data upon request;
- Grant consumers the right to request businesses that sell personal information or disclose it for a business purpose to disclose the categories of information that it collects and categories of information and the identity of 3rd parties to which the information was sold or disclosed.
- Authorize consumers to opt out of the sale of personal information by a business and prohibits businesses from discriminating against the consumer for exercising this right;
- Authorize businesses to offer financial incentives for collection of personal information; and
- Prohibit businesses from selling the personal information of a consumer under 16 years of age unless authorized to do so.

3.3 May Promote Improved Public Acceptance and Familiarity with RUC

Fuel taxes are collected high in the fuel distribution chain and are imbedded in the price of fuel paid by motorists. Thus, fuel taxes are relatively easy to enforce today. There is also a general unawareness by motorists that they are even paying a fuel tax in the first place. However, a RUC on personal vehicles would require vehicle owners to pay a different fee by a different method that is much more visible and likely to be viewed negatively by the public. As noted before, AVs may be predominantly deployed by MaaS providers with an accompanying shift in traditional vehicle ownership model with fixed, sunk costs to more subscription-based approaches. In this case, a RUC on MaaS services is more palatable as these users will already be paying some sort of new fee, but it will be for a service they are familiar with and are comfortable paying for on a trip-by-trip basis. An analogous fee model is the levying of state and federal taxes on cell phone bills. Furthermore, paying RUC on a recurring (per-use) basis through MaaS subscriptions may increase acceptability relative to options that would collect RUC less frequently. Most states have pilot tested systems that collect RUC on a monthly basis, and some states are exploring the potential to levy RUC in conjunction with annual fees like vehicle registration, would could impose a significant additional annual cost on some drivers. By levying RUC in conjunction with MaaS, users are charged each time they use the service, so total cost is spread out over time.

3.4 Enhanced Information for Capital Project Planning

Currently, capital planning programs and major transportation investments rely on information provided by infrastructure-based sensors and historical data. However, the wealth of technology within an AV can support the creation of more robust transportation datasets that can be used to improve highway infrastructure planning and investment. The sensor suites within an AV create a real-world environment showing all of the surrounding elements not only of the AV, but also the vehicles around it. By levying a RUC on AVs, certain data provisions could be made with the AV owner or technology provider that provide key AV data without impeding motorist privacy. This data could be coupled with existing infrastructure-based data sources to provide more accurate information which planners could use to design more efficient roadways.

3.5 Real-Time Transportation Network System Management and Performance Monitoring

Local agencies are exploring the use of technology for the improve connectivity, accessibility and improve awareness of infrastructure assets and system performance. The data provided by AVs can be collected in real time to provide enhanced system management and performance monitoring capabilities that, in turn, support more proactive roadway operations as part of such "Smart City" initiatives. This means agencies can better manage traffic controls like signals, provide safer incident response services, and better coordinate roadway maintenance activities. Information provided by AVs can show accidents as they occur, display the impacts of roadway and weather conditions on overall traffic, and identify and navigate alternate routes. If mutually agreeable data provisions between the state, the motorist, and technology provider can be established, the enhanced data provided by these AV systems under a RUC system could support real-time transportation network system management and performance monitoring.

4 ASSOCIATED RISKS

Coupled with the benefits of levying a RUC on AVs, there are also several risks that should be considered:

- Decreased public acceptance of AVs
- Decreased market penetration from MaaS providers
- Proprietary systems and data ownership
- Organizational complexities

4.1 DECREASED PUBLIC ACCEPTANCE OF AVS

While relatively new in their lifecycle, AVs are already making an impact on public perceptions of and expectations for transportation infrastructure. Although many believe AV deployments are inevitable, AV systems are at the same time not very popular. A Pew Research Center survey of 4,135 U.S. adults conducted in May, 2017, showed that while 65 percent of survey takers believe that most cars will be driverless within the next 50-years (Figure 4), 56 percent would not want to ride in an autonomous vehicle (Figure 5).

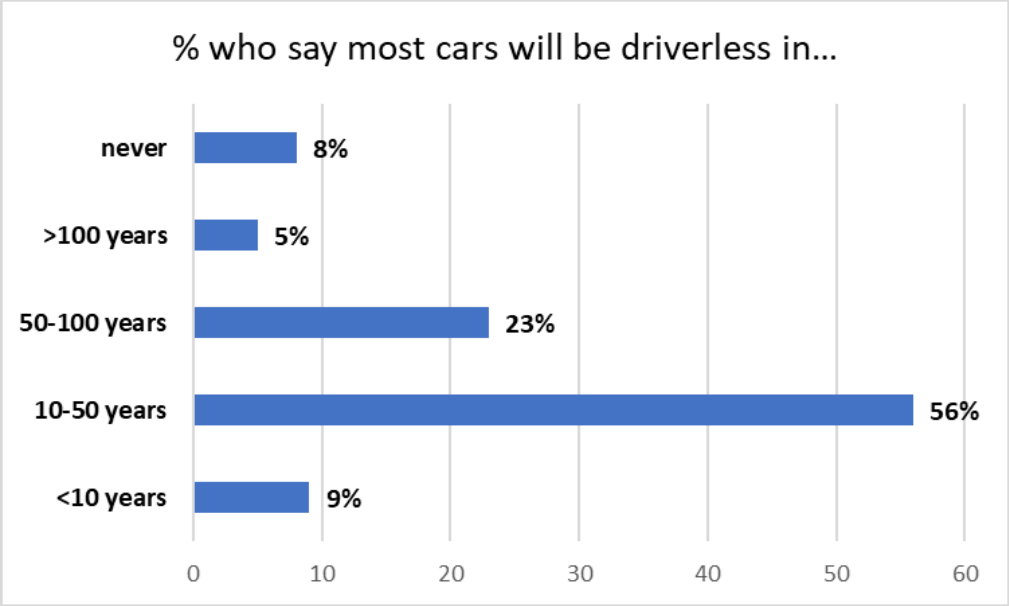

Figure 4: Survey Results of When Most Cars will be Driverless[10]

[10] http://www.pewinternet.org/2017/10/04/automation-in-everyday-life/

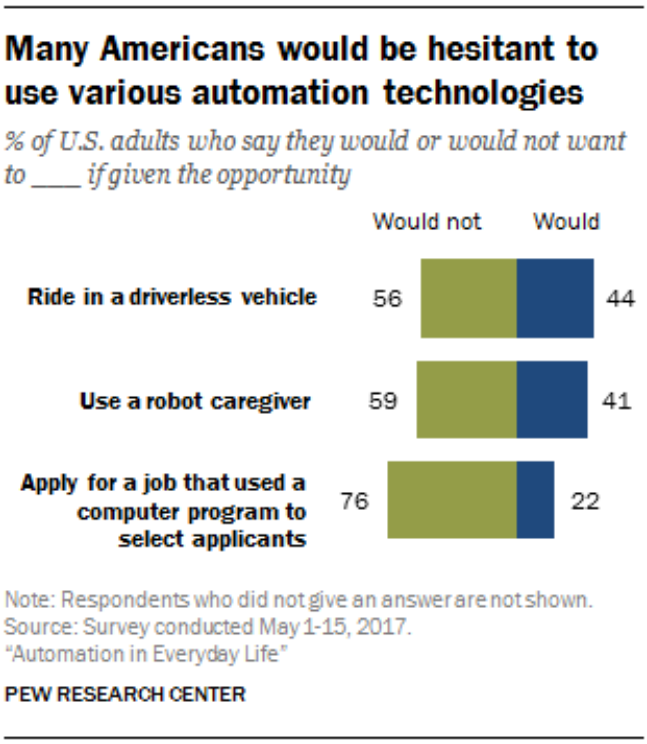

Figure 5: Survey Results of Desires to Ride in an Autonomous Vehicle[11]

Based on these results, public opinion of AVs is low relative to the attention they receive. If coupled with an already unpopular opinion of RUC, AVs may become less popular among the public and future deployments may be hindered. This could pose a risk to the increased emergence of AVs and their anticipated safety, convenience, and other mobility benefits. Furthermore, this may negatively impact the potential revenues recognized through a RUC on AV program.

One potential mitigation strategy could be the creation of a public education campaign that furthers education on transportation funding, the impact and benefits that AVs can bring to motorists, and how states can collaborate with AV providers and their motorists to promote safer roadways through the enhanced funding a RUC could bring.

4.2 Decreased Market Penetration from MaaS providers

Coupled with the decrease in public support for AVs, imposing a RUC on AVs (and especially those used by MaaS providers) could negatively impact how quickly MaaS providers enter and expand within state mobility markets. Most MaaS providers are for-profit companies and do not wish to be burdened with additional fees or taxes for their services. As such, MaaS providers may choose to not offer AV-based mobility services in markets where a RUC is levied. This could result in a decrease in market penetration for MaaS providers which may further public dissatisfaction with RUC and negatively impact both revenues as well as transportation network performance.

[11] http://www.pewinternet.org/2017/10/04/automation-in-everyday-life/

One possible mitigation would be to collaborate with major MaaS providers (Uber, Lyft, and carshare companies) who are investing in AVs and identify any fees or processes that can be streamlined through a RUC program. A major selling point for RUC service providers in the commercial vehicle sector is the ability to automatically report the myriad of state fees and taxes required of interstate truckers; consolidating and automating the reporting of applicable state, local and regional fees for MaaS providers could be a similarly attractive incentive for support of RUC. This collaborative effort could develop policies that improve overall MaaS viability while still allowing states to recognize the potential revenues a RUC program can bring.

4.3 Proprietary Systems and Data Ownership

In order to assess and audit a RUC imposed on AVs, certain types of data must be made available. Generally, this data includes: aggregated mileage, fuel consumption, and location (in certain instances). Audits may include even more trip specific data such as date/time, trip duration, and the vehicle within which those trips occurred. To further recognize the benefits AVs can bring to transportation operations, even more data may be required (e.g. speed, emissions, idling, vehicle diagnostics, hard braking, etc.). However, as valuable as this data is, there is a disparity between what entities own the data and how it can be shared which poses a risk to the overall success of levying a RUC on AVs. MaaS and AV service providers may seek to monetize data for other users, but a RUC may place requirements on how and when vehicular and driver data can be used outside of RUC assessment. If data ownership cannot be defined through legislative policy, then the ability to account for and audit the revenues from a RUC may be at risk.

Data ownership and the conditions within which that data can be shared is a complicated process. A study conducted by the Texas Transportation Institute in 2016 examined data ownership issues with connected cars from the perspective of three different stakeholder groups: automobile original equipment manufacturers, infrastructure facility owner-operators, and data aggregators. Automobile manufacturers acknowledge that the owner or lessee of the car is the owner of the data; however, manufacturers can access and control the data through subscription user agreements. Data aggregators, or service providers, consider themselves to be the owners of the information that they sell, which is derived from the vehicular data. Infrastructure owner-operators consider themselves to be the owners of the data collected by the roadside sensors and equipment which they purchased and installed.[12]

One strategy to help mitigate data ownership risks is to work directly with the OEMs, infrastructure owners, and data aggregators to clearly identify the types of data that would be required for RUC, how that data could be reused, and how the states could utilize the data provided by AVs. Once a mutually agreeable set of terms is established, policies could then be adopted to both launch a RUC program, as well as clearly define the terms of data ownership and usage.

[12] https://static.tti.tamu.edu/tti.tamu.edu/documents/165604-1.pdf

4.4 Organizational Complexities

Levying a RUC on AVs also poses a set of organizational complexities. Whether RUC is imposed solely on AVs or for all vehicles, the organizational complexities of establishing a new tax program poses a risk to overall program success. Currently, RUC programs are being researched, demonstrated, and (in the case of Oregon), administered by state Departments of Transportation (DOTs). However, state tax programs are generally administered by departments of revenue who may have separate, disparate systems. Furthermore, vehicular enforcement programs, like inspection or registration, are generally conducted by departments of motor vehicles that are often independent or within another state department such as transportation or commerce. For a new tax program like RUC to be successfully deployed, it will require involvement from many agencies, many of which lie outside of the state DOTs currently exploring the RUC concept.

Many studies have been previously conducted by RUC West and its member states to explore ways other state agencies will need to be involved and their systems integrated into a RUC program. Furthermore, several ongoing or previously conducted RUC pilot demonstrations have established notional organizational frameworks for administering RUC programs. Many states are also establishing AV task forces that are focused on furthering AV studies in their respective states.

One potential mitigation strategy would be to link the organizational efforts of RUC with AV task force efforts to determine the optimal administrative framework for administering a RUC on AVs. Through these efforts, and possible subsequent policies, an administrative organization that focuses on both the advancement of RUC and AVs could be recognized.

5 NOTIONAL REVENUE FORECAST AND ASSUMPTIONS

This section provides a notional revenue forecast to identify the potential revenues that could be recognized by imposing a RUC on AVs. The results of this forecast and the assumptions used in the analyses are for notional purposes. As each state is unique and has their own policy considerations, each state's revenue forecasts should be evaluated on a state by state basis.

The RUC on AV revenue forecast is based on the same formula used in current RUC programs:

$$Net\ RUC = [(Average\ VMT * RUC\ rate)] - \left[\frac{(Average\ VMT)}{(Average\ fuel\ economy)} * (State\ gas\ tax)\right] - [Admin.Cost]$$

The calculations used in the revenue analysis are based on VMT, average fuel economy, and quantities of vehicles registered in the US. This data, available from several sources, was then extrapolated to determine the potential quantity of vehicles that could be AVs, the powertrains which would propel the AVs, the VMT which AVs may be expected to travel in a year, and the average fuel economy of AVs under each powertrain. The per-mile rate was set to a constant value, based on the base year average fuel economy and the current state gas tax rates. Growth rates for vehicle quantities, powertrain composition, fuel economy, and VMT were also identified an included in the analysis.

To determine the values for these calculations, as series of assumptions was established. These assumptions are based on both available data as well as estimates from other programs. Details on the assumptions used in the forecast are provided below.

5.1 ASSUMPTIONS USED IN THE REVENUE FORECAST

There are several key assumptions used to develop the notional revenue forecast. The forecasting of AV RUC revenues is based foundationally on vehicle counts available for each state, and the average annual miles travelled (VMT) for each vehicle. To establish a baseline on these values, the analysis took previously provided data from various federal sources. Total vehicle passenger counts were captured using 2016 state vehicle registration data.

Fuel economy was also calculated, using 20 miles per gallon (MPG) which was also used as the base fuel economy for the Oregon, California, and Colorado RUC pilot demonstrations. Note this average fuel economy was only calculated using Internal Combustion Engine (ICE) powertrains. As hybrid electric and battery electric vehicles provide a much higher estimated miles per gallon value (ranging from 45 MPP to over 100 MPGe), those fuel economies were calculated separately, as they would skew the overall analysis. An average annual increase in fuel economy of 2.02% was also calculated. This percent change was calculated using the difference in fuel economy between Model Year (MY) 2016 vehicles and MY 2017 vehicle sales.

Then, a conservative base concentration of AVs relative to overall vehicle counts was identified. This value is currently assumed to be 0.5%. While some RUC West states who are aggressively exploring AVs, such as California and Nevada, may have higher concentrations, other states may have less of a concentration, hence the conservative concentration value. Additionally, a 0.5% annual growth rate of

AVs, as a concentration of total state vehicle counts, was also assumed. Again, this growth rate may greatly vary between states but a baseline, possibly overly conservative, concentration was assumed.

The per-mile RUC rate used in the analysis was then calculated. The per-mile rate for each state was calculated using the 2018 state gas tax values for each RUC West state, divided by the assumed average fuel economy for ICE powertrains (20 MPG). Again, the fuel economy of hybrid electric vehicles and battery electric vehicles was not taken into consideration when calculating the per-mile rate. Finally, as most states will require legislative action to either implement or change a per-mile rate, and the introduction of potential legislation poses a level of uncertainty, the per-mile rate used in the revenue analysis remains constant over the course of the revenue forecast.

Next, to prevent double taxation from the analysis, it was assumed that any vehicles that are gasoline powered (i.e. contain an internal combustion or hybrid electric engine) will receive some sort of credit on their state gas taxes. This credit is calculated based on the miles travelled, divided by the average fuel economy for the year those miles were travelled, using the current state gas tax values for each RUC West state.

To determine the number of AVs that would be subject to a gas tax credit, the 2017 AV powertrain percentages (58% EV, 21% ICE, 21% Hybrid Electric) were used for the baseline year. Also, a 3% annual change in the powertrain compositions for AVs was assumed, where the powertrains for EVs will migrate from ICE to electric. Caps of 1% for AVs powered by internal combustion engines and 4% for AVs powered by hybrid electric engines were established (meaning that over the course of the forecast, no less than 1% of all AVs will be powered by ICE and no less than 4% of all AVs will be powered by hybrid electric powertrains).

Finally, average annual VMT was assumed for the duration of the forecast. A value of 48,000 miles per year for AVs was assumed. This assumption is based on AVs being used solely in a Mobility as a Service or rideshare environment, and travel an estimated four times more a year than private owned vehicles (which average 12,000 annual VMT). While states that have a robust MaaS market may skew the baseline VMT to much larger numbers, other states may not have as robust a market for MaaS, hence the more conservative estimate of four times the average private vehicle VMT. Finally, a 2% annual growth rate in VMT is assumed, as calculated as the difference between federal VMT numbers from 2016 and 2017. While some analyses actually suggest that AVs will lead to a decrease in overall VMT, there is a considerable amount of variability in these forecasts and a decline in overall VMT is not used in this forecast.

Finally, administrative costs for the RUC program were assumed. Current pilot demonstrations have identified a wide array of costs as a percentage of overall revenue. The Oregon RUC program, OReGO, calculates that collection costs for their 5,000-person opt-in program are approximately 40% of total revenues, but Oregon anticipates this number to fall below 10% as the number of vehicles in the OReGO program expands to the hundreds of thousands[13]. The New Zealand Mileage-based User Fee program currently collects RUC from over 150,000 heavy vehicles and 600,000 light diesel vehicles at a cost to

[13] http://www.oregon.gov/ODOT/HWY/RUFPP/docs/IP-Road%20Usage%20Evaluation%20Book%20WEB_4-26.pdf

government less than 5 percent of revenues[14]. Currently, utility commissions and telecommunications companies are experiencing a collection cost percentage of between 5% and 10%[15]. Given these values, and assuming that eventually, the number of AVs will be subject to a RUC under this program will be in the hundreds of thousands, an administrative cost of 8% as a percentage of total revenues was assumed.

5.2 Revenue Forecast Results

Given the assumptions listed above, a revenue analysis for each RUC West state was conducted. The results are provided in the tables below:

[14] http://www.nzta.govt.nz/vehicles/licensing-rego/road-user-charges/about-ruc/

[15] See, e.g., San Diego Water Utility, Fresno Water Utility, Pasadena Light & Power, Technical Advisory Committee Meeting #5, May 2015, Fresno, CA

Table 1: RUC West AV Revenue Forecast, Years 1 through 10

	Base Year	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
AZ	$3,327,284	$7,291,955	$11,931,755	$17,295,427	$23,423,770	$30,363,805	$38,165,902	$46,949,136	$56,913,913	$68,071,293
CA	$45,756,899	$100,314,800	$164,187,055	$238,013,744	$322,336,178	$417,773,923	$524,994,423	$641,982,865	$765,100,316	$899,839,100
CO	$2,927,018	$6,416,703	$10,502,397	$15,224,998	$20,618,959	$26,723,725	$33,582,559	$41,065,844	$48,941,313	$57,560,111
HI	$1,809,389	$3,966,021	$6,491,708	$9,410,967	$12,744,283	$16,517,680	$20,757,493	$25,383,009	$30,250,973	$35,578,068
ID	$1,484,737	$3,255,277	$5,328,096	$7,724,062	$10,460,314	$13,557,094	$17,036,577	$20,833,027	$24,828,630	$29,200,658
MT	$1,055,346	$2,313,395	$3,786,820	$5,489,454	$7,434,282	$9,635,476	$12,108,174	$14,806,792	$17,646,034	$20,753,854
NV	$2,608,761	$5,719,051	$9,360,292	$13,568,801	$18,376,369	$23,816,634	$29,929,415	$36,598,701	$43,617,853	$51,299,023
NM	$916,209	$2,008,793	$3,287,826	$4,765,991	$6,454,655	$8,365,685	$10,512,981	$12,855,403	$15,320,997	$18,019,025
UT	$2,031,699	$4,454,165	$7,290,199	$10,568,076	$14,312,347	$18,549,765	$23,310,763	$28,505,170	$33,971,933	$39,954,223
ND	$408,388	$895,263	$1,465,474	$2,124,074	$2,876,851	$3,728,466	$4,685,183	$5,729,419	$6,828,130	$8,030,610
OK	$2,037,883	$4,467,831	$7,312,776	$10,600,717	$14,356,220	$18,606,964	$23,382,168	$28,592,893	$34,076,347	$40,077,405
OR	$3,372,101	$7,392,510	$12,099,637	$17,540,269	$23,754,202	$30,787,502	$38,688,945	$47,310,324	$56,383,378	$66,312,928
TX	$12,176,098	$26,693,444	$43,689,910	$63,334,937	$85,772,958	$111,168,849	$139,699,805	$170,830,267	$203,591,733	$239,445,502
WA	$10,510,258	$23,043,283	$37,715,209	$54,674,381	$74,043,764	$95,966,337	$120,595,787	$147,469,054	$175,750,530	$206,701,217

Table 2: RUC West AV Revenue Forecast, Years 11 through 20

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
AZ	$80,503,276	$94,312,505	$109,609,071	$124,192,251	$138,678,290	$154,181,706	$170,734,891	$188,401,937	$207,240,201	$227,317,058
CA	$1,046,686,091	$1,206,352,741	$1,379,597,457	$1,553,528,345	$1,732,603,111	$1,923,767,938	$2,127,625,810	$2,344,972,228	$2,576,478,535	$2,822,949,722
CO	$66,953,340	$77,166,941	$88,249,135	$99,374,938	$110,829,631	$123,058,145	$136,098,411	$150,001,110	$164,810,090	$180,576,162
HI	$41,384,107	$47,696,994	$54,546,857	$61,423,685	$68,504,159	$76,061,996	$84,122,896	$92,716,209	$101,869,768	$111,614,681
ID	$33,966,178	$39,147,433	$44,769,726	$50,414,037	$56,224,980	$62,428,331	$69,043,713	$76,097,176	$83,609,454	$91,607,934
MT	$24,140,753	$27,823,107	$31,818,674	$35,830,045	$39,960,157	$44,369,370	$49,071,083	$54,084,036	$59,423,135	$65,107,678
NV	$59,670,684	$68,773,117	$78,649,469	$88,565,228	$98,774,282	$109,672,361	$121,293,908	$133,684,640	$146,882,916	$160,933,841
NM	$20,959,461	$24,156,786	$27,625,882	$31,108,998	$34,694,753	$38,522,773	$42,604,845	$46,957,228	$51,593,014	$56,528,441
UT	$46,474,903	$53,563,968	$61,256,551	$68,979,292	$76,930,579	$85,418,584	$94,470,275	$104,120,638	$114,399,895	$125,343,977
ND	$9,341,430	$10,766,377	$12,312,357	$13,864,817	$15,463,060	$17,169,103	$18,988,350	$20,928,102	$22,994,133	$25,193,880
OK	$46,617,576	$53,728,919	$61,444,689	$69,191,432	$77,167,176	$85,681,211	$94,760,760	$104,440,958	$114,751,809	$125,729,079
OR	$77,134,464	$88,900,957	$101,668,056	$114,485,347	$127,682,137	$141,770,150	$156,792,793	$172,809,950	$189,870,688	$208,034,002
TX	$278,521,205	$321,008,067	$367,107,909	$413,390,608	$461,042,194	$511,910,671	$566,156,924	$623,992,412	$685,595,787	$751,181,186
WA	$240,433,443	$277,110,120	$316,905,706	$356,859,303	$397,994,391	$441,907,202	$488,734,745	$538,661,008	$591,840,394	$648,456,895

5.3 KEY TAKEAWAYS FROM FORECAST

In evaluating the results provided from the revenue model, several key takeaways are identified below:

- Gross revenues are highest for California with over $2.8 billion in annual revenue in year 20, followed by Texas with $751 million and Washington with $648 million by year 20. This can be attributed to the larger number of vehicles registered in those states. California, for example, has more registered vehicles than all other RUC West states combined not including Texas.

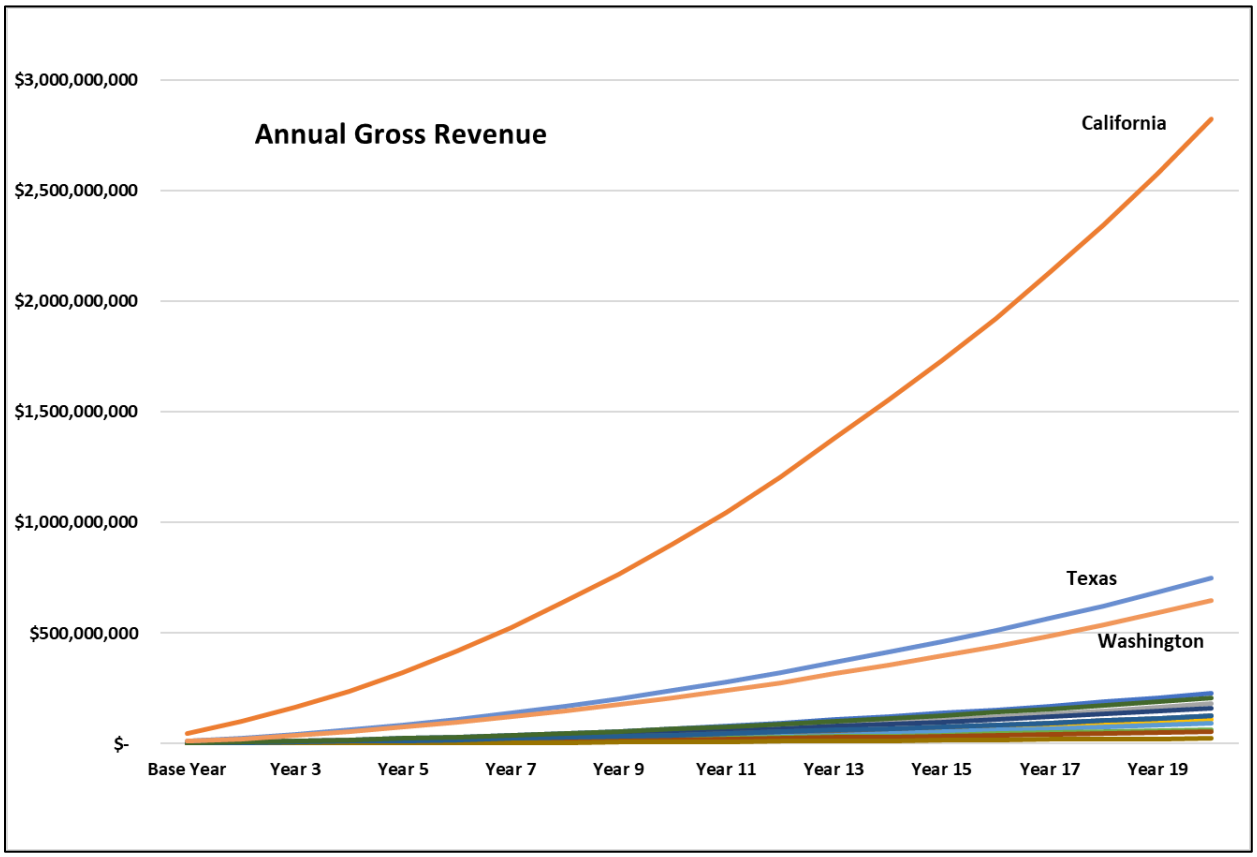

Figure 6: Annual RUC Revenue Forecast Trendline per state

- Revenues for every state increased by over 60 times in Year 20 relative to the Baseline Year. Again, this is attributed to the increase in total vehicles, as well as the decrease in internal combustion powertrains. Note that revenues for EVs, which eventually account for 95% of all vehicles in the marketplace, are subject to a per-mile RUC with no fuel tax credits being provided.

- Revenues more than double in Year 2, and while they continue to grow year-to-year, the rate of that increase declines over time. By Year 20, revenues are increasing by just under 10 percent per year.

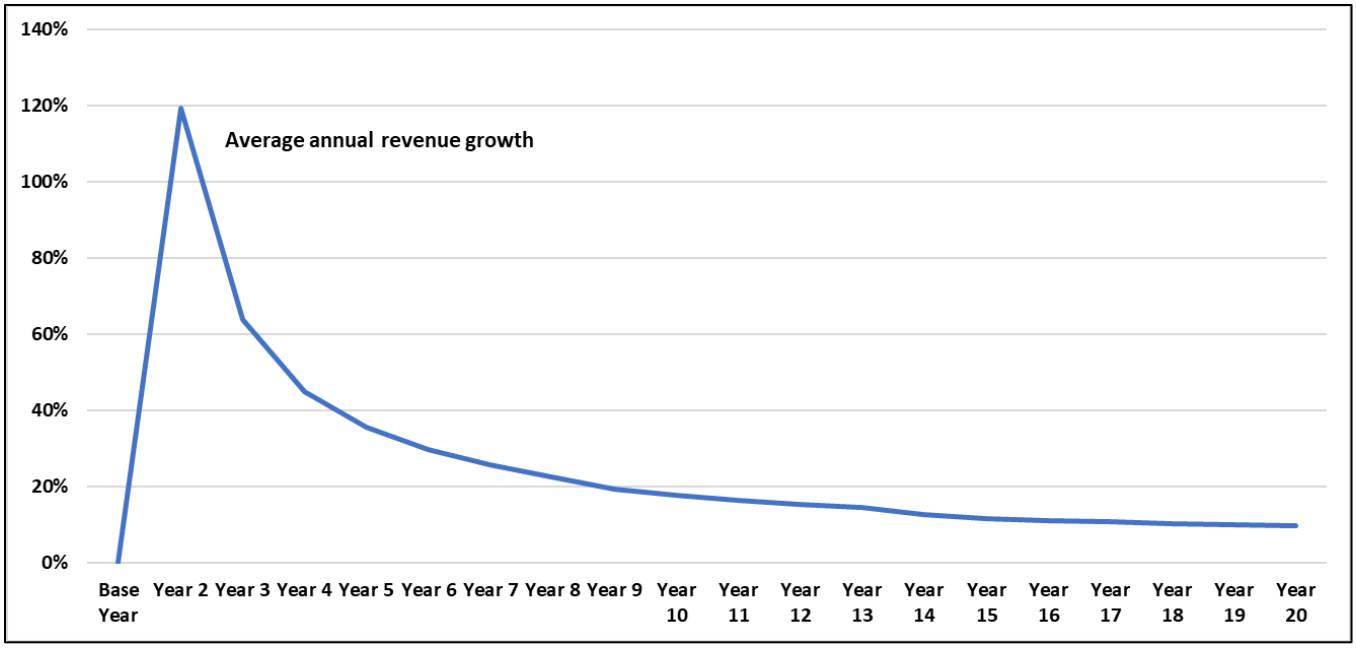

Figure 7: Percent change in RUC Revenues per Year

6 NOTIONAL SYSTEMS ENVIRONMENT

Levying a RUC on AVs will require a new systems environment, partially fulfilled by private sector data collectors and partially fulfilled by RUC West participating states. This environment will collect aggregated data and RUC from AVs and a potential mix of business partners, infrastructure providers (if needed), and data aggregators.

Given RUC West's intent to further promote RUC interoperability between states, a clearinghouse approach is proposed. This clearinghouse could collect, aggregate, and route RUC data and revenues between states based on the policy and technical considerations and requirements established between the RUC West states. Many of the other systems proposed are either already in place as part of AV testing and data analytics initiatives.

A high-level notional systems diagram showing the potential data and financial flows is provided below in Figure 6.

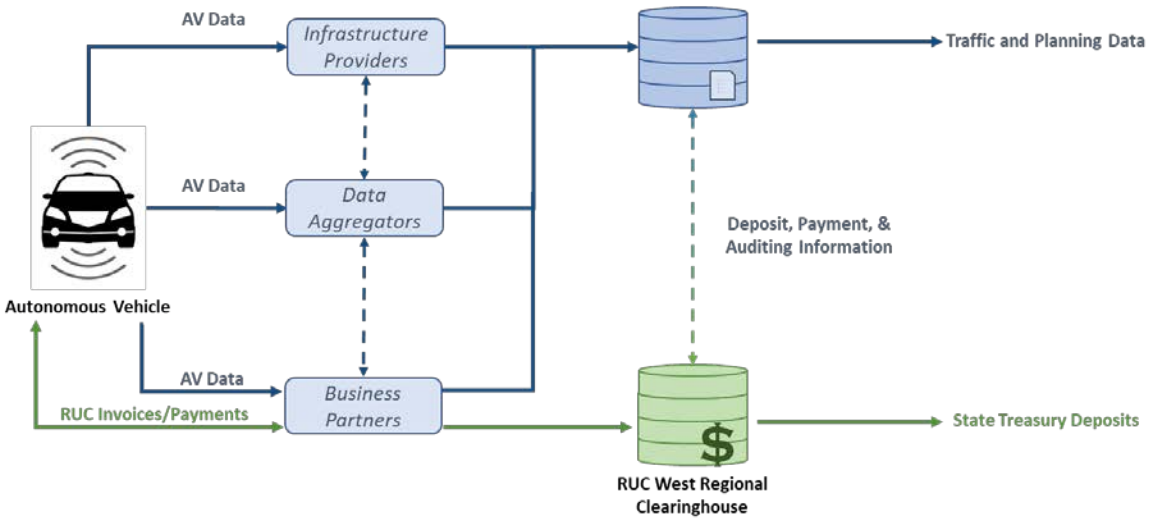

Figure 8: Notional Technical Systems Environment

Data from AVs will be transferred through other AVs (V2V), through infrastructure (V2I), and/or any other type of communications systems (V2X). This data will be sent to data reporting and analytics platforms hosted by infrastructure providers, data aggregators, and RUC business partners (who can also serve as AV service providers). The RUC specific data (VIN/Identification, Miles Travelled, Location, and Fuel consumed [if applicable]) would then be used by the business partner to assess the RUC, and route that data (plus any other agreed upon data) to the RUC West Regional Clearinghouse. The clearinghouse would then distribute the data to each participating state to support enhanced operations and planning activities. Other data provided by the AVs, but not directly used for RUC, could also be transferred to the clearinghouse, based on requirements and memorandums of understanding established between the RUC West states, the clearinghouse provider, and the infrastructure and service providers.

For the financial flow, the service provider would calculate the RUC (using the data provided and the states' per-mile rates) and submit invoices to the motorists, either deducting from prepaid accounts or

requiring the vehicle owner to pay any RUC amounts due upon invoice receipt. Any monies collected for RUC, minus agreed upon transaction fees, would then be routed from the business partner to the clearinghouse which would route the revenues and data to the appropriate states treasuries based on the miles driven in each state.

Information and data supporting RUC deposits and audits may also be shared within the clearinghouse. Depending on the requests of the audit, specific data relating to a vehicle's trip and assessed RUC may also be requested.

7 OPERATIONAL IMPACTS FOR PARTICIPATING STATES

There will be several operational impacts for states that levy a RUC on AVs. To help organize the operational impacts, groups of stakeholders have been identified and are provided below. These stakeholder groups are those who will be directly impacted by levying a RUC on AVs. Stakeholders that may be indirectly affected have been intentionally disregarded. The stakeholder groups directly affected by this program include:

- AV Owners
- AV Service Providers, Infrastructure Providers, OEMs and Data Aggregators
- RUC Business Partners
- RUC West
- Participating States

7.1 AV OWNERS

The owners of AVs (either individuals or fleet owners and MaaS providers) will be directly impacted by a RUC as they will be responsible for paying for their use of a participating state's roads. They will be responsible for any costs to comply, such as paying a subscription to a RUC business partner and requesting their AV service provider allow AV data to be used in RUC assessment. In the future, the role of the AV service and the RUC service provider may be accomplished by the same entity, removing the need for a separate subscription. Operationally, the levying of a RUC on their AV should pose little impact outside of the required review of invoices and payment of any assessed charges.

7.2 AV SERVICE PROVIDERS, INFRASTRUCTURE PROVIDERS, OEMS AND DATA AGGREGATORS

These entities collect and process AV data from the vehicles. Under a RUC program, these providers may be required to deliver RUC-specific data to RUC business partners, the RUC clearinghouse, and/or participating states. These providers may also serve as RUC Business Partners. They will be responsible for the accurate collection, analysis, and routing of AV data to RUC business partners, as well as potentially supporting customer inquiries from owners and audits from participating states. They may also be required to establish a series of Memorandums of Understanding (MOUs) with similar providers, establish common data formats for transferring RUC data and share RUC information with their subscribers.

7.3 RUC BUSINESS PARTNERS

RUC business partners are responsible for collecting, analysing, and processing RUC data, providing invoices to AV owners, collecting monies from these owners, and then transferring RUC revenues to the regional clearinghouse. This group may include OEMs responsible for developing and operating in-vehicle telematics-based applications. Operationally, they may need to modify their systems to support new data types or formats provided by AVs and establish the requisite MOUs with AV providers.

7.4 RUC West

As the information leader for this project, RUC West will be a valuable source of guidance for each state that participates in the RUC on AV program. RUC West may also choose to provide guidance and sample policies to states. RUC West may also disseminate information for use in public education campaigns and for knowledge transfer among professional organizations and between other states or entities exploring how a RUC on AV program should be deployed. Finally, as several of the RUC West states also have teams or offices focused on AV technologies and programs, RUC West may wish to establish a task force to engage these resident experts on current advancements in: AV technologies and regulations, established agreements with private partners, and any limitations in their existing programs that may prove to be obstacles in levying a RUC on AVs.

7.5 Participating States

Participating states will see the most significant impact from a RUC on AV program. These states will be responsible for establishing necessary legislation to levy a RUC on AVs and serve as the focal point for operations, certifications, and support to AV owners. Each participating state will have a role in the AV/RUC program. Those who have existing projects (either pilot demonstrations or fully implemented programs) will be responsible for updating contracts, requirements, and agreements with business partners to accommodate a RUC on AVs. Additionally, they will be responsible for managing discrepancies and disputes, conducting enforcement activities, auditing, certifying service providers and technologies, ensuring vendor compliance with data protection and other protocols, supporting adjudication activities, and managing contracts.

States without existing programs will need to not only support the operations mentioned above, but also create the necessary designs, requirements, contracts, and administrative and operational activities needed to support a new RUC program. As several states have already accomplished many of these activities through pilot demonstrations or implemented programs, these new states may wish to rely on the activities and developments already conducted by other states.

Additionally, participating states may choose to integrate other offices within their existing agencies who may benefit from the information provided by AV and RUC programs (either disparate or combined). Traffic operations, ITS, Offices of Innovation, Planning and Research, and departments of commerce, revenue, and motor vehicle registrations may all benefit from the enhanced information an AV program may bring. As such, the RUC West representative from each state may choose to educate these groups on RUC West activities and capture any considerations or recommendations that should be brought forward to RUC West for the benefit of all states involved.

As more RUC West states become involved in a RUC on AV program, the specific roles and responsibilities of each participating state will more than likely evolve. As such, the states, and RUC West as the informational body (with potential administrative responsibilities), should continue sharing information, lessons learned from existing projects, and continue supporting research activities related to both AVs and RUC.

8 CONCLUSION

The recent technological boom of AVs provides an opportunity for RUC West and its participating states to explore the possibility of levying a RUC on AVs to help create a more sustainable model of transportation funding. This business case has presented some key considerations that RUC West may choose to explore.

Several key benefits of assessing a RUC on AVs have been identified including:

- Provide a more sustainable transportation funding source with improved revenues;
- Privacy concerns could be mitigated;
- Linking RUC payment with services users are familiar and comfortable with;
- Enhanced information for capital project planning; and
- Real-time transportation network performance monitoring.

Additionally, some key risks were identified such as:

- Decreased public acceptance of AVs;
- Decreased market penetration from MaaS providers;
- Proprietary systems and data ownership; and
- Organizational complexities.

Additionally, there are some potential next steps which RUC West and their participating states may choose to consider:

Refine this Business Case and Revenue Analysis -- Refine the results in this business case and the notional revenue analysis to each participating state's expectations.

Monitor Trends in AV Development and Usage – Track ongoing developments in the AV market, track adoption rates and use patterns once AVs become available, refine business case based on these trends.

Educate Policymakers -- Begin educating key policymakers and other local and state transportation officials on the business and economic feasibility of levying a RUC on AVs.

Collaborate with MaaS Providers – Initiate a dialog with MaaS providers to identify opportunities and barriers to implementation of RUC in conjunction with MaaS, include MaaS service providers in subsequent pilot design and discussions on regulatory frameworks, recruit MaaS providers for subsequent trials.

Conduct Systems and Resource Gap Analysis -- Begin identifying the necessary systems and other resources within each state that may be operationally impacted by a RUC, identify any existing gaps, and develop upgrade plans and associated costs to make the systems and resources operationally capable of supporting a RUC program on AVs.

Gather Existing Policies, Regulations, and Lessons Learned -- Meet with state agencies, test facilities, universities, and professional organizations (AAMVA) who are already establishing policies on AV deployments. Determine lessons learned and gather any relevant information that could be used to support further research for integrating RUC and AV projects.

Conduct AV Demonstrations – Partner with MaaS providers, OEMs, and other AV Service Providers and Data Aggregators to pilot test and evaluate AV-based RUC applications.