WA RUC

Appendix B-4: Detailed Approach and Findings from the AutoPilot Embedded Vehicle Telematics Follow-On Experience

December 2023

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PREFACE

Forward Drive was a research, development, demonstration, and public engagement effort of the Washington State Transportation Commission. The project sought to advance understanding of and implementation pathways for per-mile road usage charging (RUC) as an alternative to motor fuel taxes and alternative fuel vehicle registration surcharges. The project aimed to address several key issues for RUC including principally equity, user experience, and cost of collection. As reported in Volume 1, the project unfolded in several stages. A series of appendices contain more detailed results. These appendices are organized as explained and illustrated below.

Appendix A. Forward Drive began with research spanning several activities including financial analysis, equity outreach and analysis, user experience research, and cost of collection reduction workshops (Appendices A-1 through A-4, respectively). The purpose of the research was to explore the financial, equity, user experience, and cost impacts of RUC under a variety of deployment scenarios. This research informed the design of experience-based simulations and pilots of various elements of a RUC program.

Appendix B. The research stage led directly to the design and development of simulations and pilots of RUC program elements spanning several areas to reflect the multiple objectives and research findings. The centerpiece of the simulation and pilot testing stage was an interactive simulation of RUC enrollment, reporting, and payment. As described in Volume 1, the simulation offered over 1,100 Washingtonians an opportunity to experience RUC in as little as a few minutes, followed by a survey about their preferences and opinions. The detailed results of the simulation survey and the measurements of the simulation itself are presented as separate reports (B-1 and B-2, respectively).

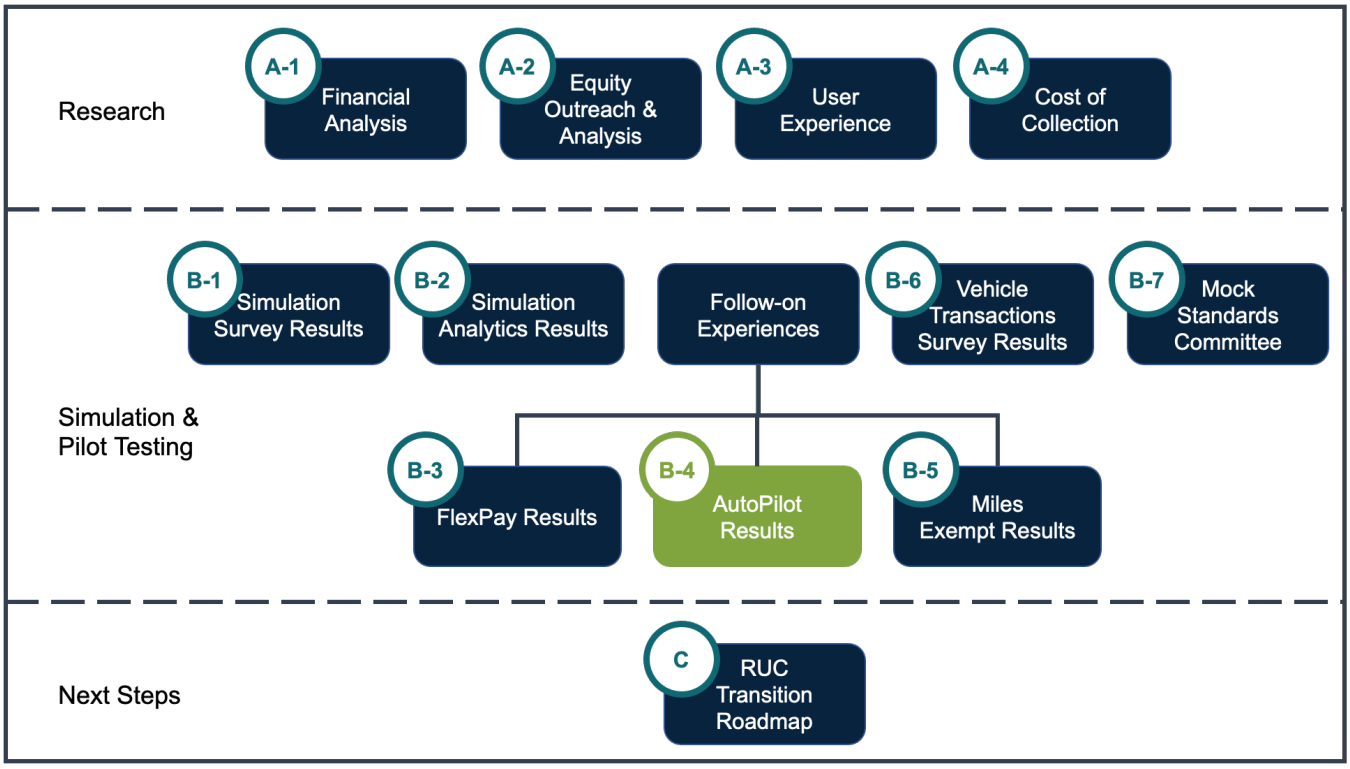
Within the simulation, participants could opt into one of three follow-on experiences, each designed to further test a specific feature of RUC of interest to Washington stakeholders and policymakers:

- FlexPay tested installment payments, allowing participants to pay their RUC over four payments instead of all at once (B-3).
- AutoPilot tested using native automaker telematics to report road usage as an alternative to self-reporting or other technology-based approaches to reporting (B-4).
- MilesExempt tested a self-reporting approach for claiming miles exempt from charges, such as off-road and out-of-state driving (B-5).

The simulation and pilot testing stage also included a statewide survey of Washingtonians' vehicle transactions designed to understand existing transactions and preferences and possibilities for how RUC reporting and payment could potentially be bundled with such transactions (B-6).

Lastly, the simulation and pilot testing stage included a mock standards committee of RUC experts from jurisdictions and industry. The committee simulated the process of creating standards for RUC to support cost reduction, enhanced user experiences, and multi-jurisdictional interoperability (B-7).

Appendix C. Appendix C details a transition roadmap for RUC in Washington drawing on the results of the research and simulation and pilot testing, as well as the updated recommendations regarding RUC implementation from the Commission to the Washington Legislature in 2022.



Appendix B-4 covers detailed results from the AutoPilot follow-on experience, including methodology, survey results, and key findings.

1.0 INTRODUCTION

Within the Washington Road Usage Charge (WA RUC) Simulation, the “AutoPilot” follow-on experience explored how to use embedded telematics technology already installed by Original Equipment Manufacturers (OEMs) to automatically report vehicle mileage and calculate monthly road usage charges. The prospects of embedded telematics for road-usage charging are promising since it offers flexibility and convenience to comply with a RUC program. While encouraging, many questions remain about technical feasibility, accuracy, data consistency, privacy protection, and cost. The AutoPilot follow-on experience assessed the viability of using embedded telematics to reduce the RUC reporting burden that comes with other less advanced methods. As part of this study, the research team assessed how mileage data would be collected, processed, and integrated as well as the challenges of collecting telematics data from various automakers.

This document first describes the objectives and key questions to address before presenting the approach that was followed in designing and conducting the experience. Characteristics of the participant sample are then reviewed. Finally, the main results and key takeaways from the experience are summarized.

2.0 OBJECTIVES

The general objectives of the AutoPilot experience were to:

- Provide a seamless customer experience to comply with a RUC system
- Reduce touchpoints for customers
- Estimate cost of collection and processing
- Delineate a telematics-based RUC process to highlight key process steps and functional flows (i.e., from automakers through data aggregators to account managers to the state)
- Identify and evaluate potential implementation issues

This experience relates to two overarching goals of the WA RUC program: cost reduction and user experience. The main questions that the experience was designed to investigate include:

- Is it technically feasible to comply with a RUC program by gathering accurate mileage data from in-vehicle telematics?
- What encourages drivers to opt for in-vehicle telematics over other mileage reporting choices?
- What technological, system, and business issues must a scalable telematics program overcome?

3.0 APPROACH

The overall AutoPilot experience process and timeline are illustrated in Figure 1. Participation in the AutoPilot required: expressing interest in the follow-on experience during the RUC simulation, signing a participant agreement, entering vehicle identification number (VIN) to determine eligibility, reviewing monthly mock invoices, answering a brief questionnaire with each mock invoice, and filling out an online survey questionnaire at the end of the experience.

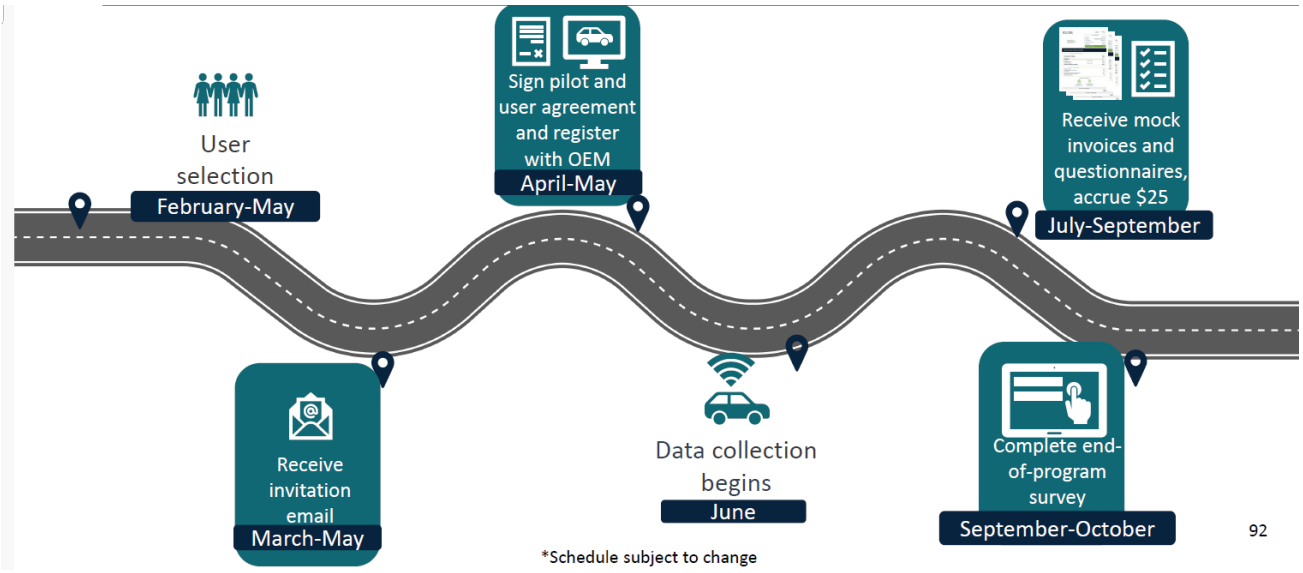


Figure 1: AutoPilot Participant Experience Workflow

3.1 Enrollment

As with other follow-on experiences, due to limitation in the Ipsos KnowledgePanel® of statistically-valid panel respondents, participants were drawn from the organically-recruited simulation participants based on their interest in embedded telematics. Participants underwent a pre-screening procedure based on the make, model, and age of their vehicles. Due to technological limitations, not all vehicles have telematics capabilities, and among those with capabilities, not all were compatible for the AutoPilot experience. Only those who chose to participate in the AutoPilot follow-on experience with pre-screened vehicles were selected.

Selected participants were required to sign a participant agreement and provide their vehicle identification number (VIN) to verify their vehicle eligibility with the OEMs. Only those with eligible vehicles continued on. Of the 32 people who opted in, 30 owned Teslas, one owned a Ram, and one owned a Jeep. The two non-Tesla participants were unable to continue their involvement due to vehicle compatibility issues. This challenge was mitigated by the generosity of two other participants with compatible vehicles who volunteered to support the research objectives.

3.2 Data Collection

Via Mobility ("Via") supplied the technology for this follow-on experience. Via acquired data from two sources for this project: Stellantis (through Free2Move, a mobility data subsidiary) and Smartcar. Each approach came with advantages and challenges. In both cases, data were gathered through API calls,

which provided in-the-moment information from vehicles. Historical data was not available through either data source. Once acquired, data were stored in a Postgres[1] database by Via until they could be analyzed at the end of each month. For all vehicles, Via first acquired VINs from consenting participants as well as information on owner name, vehicle make, vehicle model, and ZIP code.

3.2.1 Stellantis Data (Direct Approach)

Stellantis is an original equipment manufacturer (OEM) which owns fourteen brands, including Chrysler, Dodge, Fiat, Jeep, and Ram. Data from Stellantis vehicles were acquired through Free2Move, a subsidiary of Stellantis (later folded into a new, data-focused subsidiary Mobilisights), which gathers and analyzes data across Stellantis brands. The first step was to verify the eligibility of each participant's vehicle through the Free2Move VIN check. For eligible vehicles, getting data through Stellantis was straightforward. An extensive suite of data fields was available for each vehicle, with no restrictions on the frequency with which data could be requested from the vehicle and an easy API setup process, with no issues once a connection was established. Challenges primarily revolved around vehicle eligibility, with only vehicles of certain years, models, makes, and trims being eligible (and with shifting eligibility due to ongoing software updates).

- Query method: Via calls the Free2Move API using Python
- Query frequency: Every 5 seconds
- Vehicle makes: Jeep, Chrysler
- Relevant data gathered for each VIN:
    - Capture date and time
    - Fuel level and percentage
    - Battery capacity percentage
    - Odometer reading
    - Latitude, longitude, altitude
- Data handling/source: Vehicles share data with Stellantis on an ongoing basis, and Via's API calls access this data without requiring direct communication to the vehicles
- Data collection period: Three months

3.2.2 Smartcar Data (Indirect Approach)

Smartcar is a third-party data platform which can facilitate data acquisition from various brands, as long as users are willing to share their connected vehicle login information. The primary benefit of Smartcar is that the third-party connection enables partners to gather data from a broader suite of vehicles, without being constrained by an OEM's interest in participating in RUC projects. One constraint to Smartcar data access is the 60-minute frequency at which the company recommends calling the API, as each call drains vehicle battery, especially for electric vehicles like Tesla's due to the nature of the third-party connection. Data is also somewhat limited, with some information such as location or fuel levels not available for all makes. For example, with the exception of Tesla and a few other makes,

[1] Relational database management system to store and retrieve large amounts of data.

location data can only be accessed after a vehicle is parked. Finally, Smartcar has a more complex process for API calls than Stellantis and can place restrictions on data volume, which can lead to temporary disconnections and result in up to a day of data loss while an issue is triaged with the technical team.

- Query method: Via calls the Smartcar API using Python
- Query frequency: Every 60 minutes
- Vehicle makes: Tesla
- Relevant data gathered for each VIN:
    - Capture date and time
    - Latitude
    - Longitude
    - Odometer reading
- Data handling/source: With each API call, the call contacts the vehicle and shares that data through the API. Smartcar is not able to see the data and does not store it, only requesting and sending the data rather than reading it.
- Data delivery format: Plain text
- Data storage format: Database using numeric fields
- Data collection period: Two months

3.3 Data Processing

Once data were received and stored in Postgres, an SQL database, they were processed using the statistical coding language R. The data from Stellantis/Free2Move and smartcar were processed using two separate scripts to handle the different format data was saved in and to account for the different volumes of data coming from each of the providers. On average, data processing took one week after data collection finished for a given month. Data was delivered in Excel format to CDM Smith, with a separate tab for each month of participant data. The process for Stellantis vehicles followed the following steps:

- Read one day of data at a time
- For each vehicle, sort the data entries by time
- Calculate whether the vehicle was inside or outside of Washington, and calculate the mileage and gas used since the previous reading.
- Aggregate mileage and gas usage inside and outside Washington state for each vehicle
- Aggregate mileage and gas usage inside and outside Washington state over multiple days in a month.

The process for Tesla vehicles with Smartcar followed the following steps:

- Read a full month of data

- For each vehicle, sort the data entries by time
- Calculate whether the vehicle was inside or outside of Washington, and calculate the mileage and gas used since the previous reading.
- Aggregate mileage and gas usage inside and outside Washington state for each vehicle

Calculation of whether the vehicle was in or out of Washington was done by comparing vehicle location (latitude and longitude) with the shape file of the state of Washington. The shape file was extracted from the Census Bureau's website on May 18, 2023. The comparison was done using the R function Spatial Points in the package sp. The distance between each two consecutive location reads was attributed to the later location: if the later location was in Washington, the whole distance calculated based on the odometer between the two location reads was allocated to driving within the state.

3.4 Mock Invoices

The data processing was used to create simulated invoices to help communicate information about RUC and its impacts to motorists in a personalized manner. The mock invoices were used to showcase the net amount of RUC incurred. No real money was exchanged, but participants had an opportunity to evaluate the costs associated with RUC, net of gas taxes paid. Invoices also provided participants an opportunity to check the accuracy of the reported charges. The research team designed personalized invoice templates for this user group to improve customer engagement. Stellantis vehicle owners received three rounds of mock billing cycles while Tesla owners received two mock billing cycles. The difference was because the two Stellantis participants were essentially test vehicles with verified telematics connections. The same degree of connectivity testing was required for the broader group of Tesla participants, with 30 days of testing before launch. The output was a single csv file that included the following fields for each VIN:

- Vehicle miles traveled (total)
- Vehicle miles traveled (in Washington)
- Vehicle miles traveled (out of Washington)
- Total gas consumed (gallons)
- Gas consumed in Washington(gallons)
- Vehicle fuel economy (MPG)
- Washington road usage charge rate per mile
- Washington road usage charges
- Washington gas tax rate (per gallon)
- Washington estimated paid gas taxes

Fields regarding participants were then added using Excel, including:

- First name
- Last name
- ZIP code
- Period of collection (Month)

- Vehicle make
- Vehicle model
- Vehicle year

Income-based discounts selected during the simulation were added, as appropriate. Aside from tailoring the invoice experience for each participant with RUC incurred, Frequently Asked Questions (FAQs) were incorporated within the mock invoices to enhance participants' understanding of RUC. This proactive approach promoted RUC understanding and transparency.

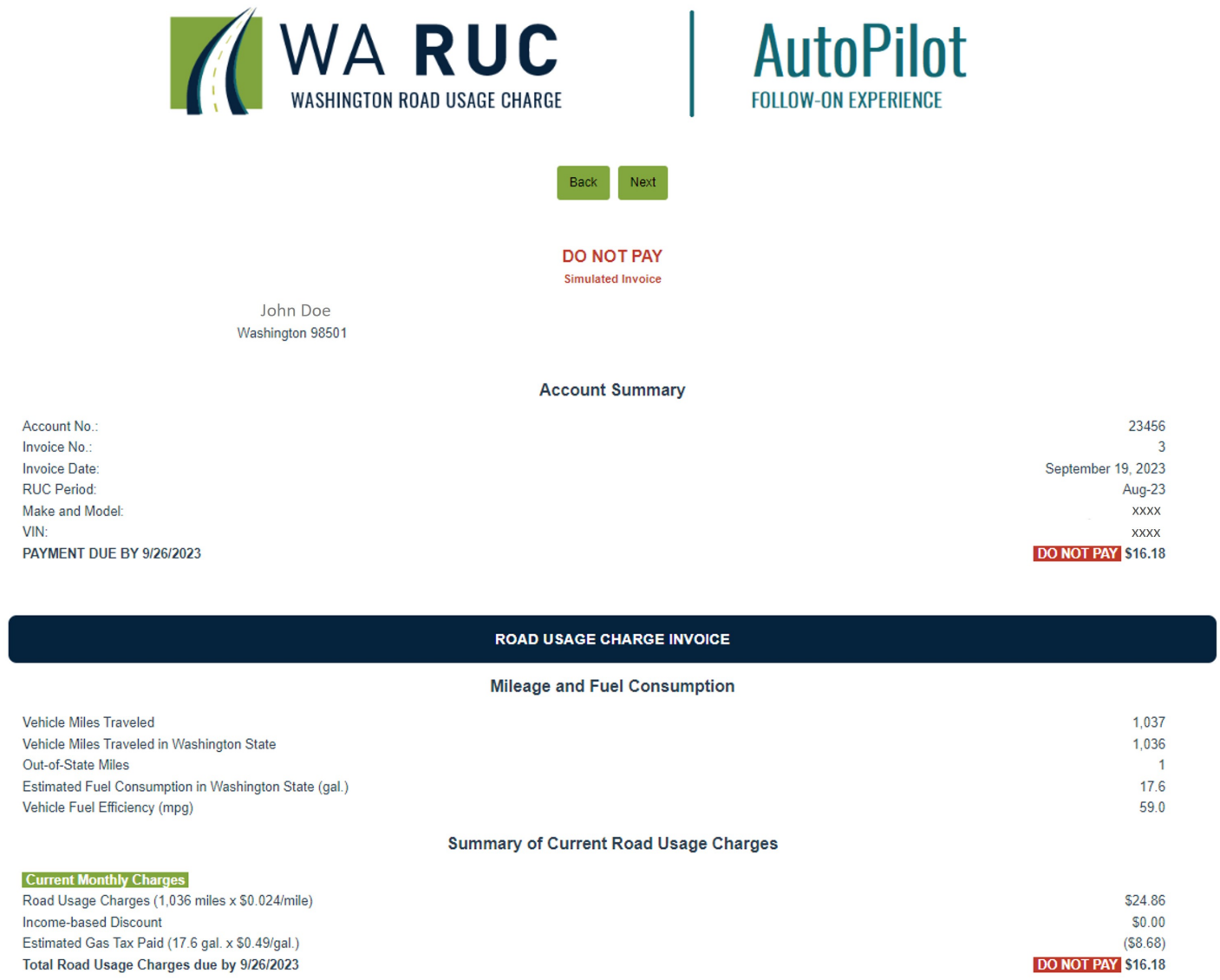


Figure 2: Mock Invoice Template

The following are the frequently asked questions in the mock invoices:

- **What is a road usage charge?**
  A road usage charge is a per-mile charge drivers would pay based on how much they use Washington's road system rather than by the gallons of gas they buy.

- **What is the per-mile rate of the Road Usage Charge?**
  The rate is 2.4 cents per mile. This is what the average Washington vehicle currently pays in state gas taxes at 49.4 cents per gallon. How-ever, most vehicles actually pay more or less than this number. Under a road usage charge, all vehicles would pay the same. Ultimately it is up to the Legislature to establish a rate.
- **Why is Washington state studying a road usage charge system?**
  To ensure sustainable, long-term funding: As vehicles become more fuel efficient, gas consumption goes down. With a decline in gas consumption comes reduced gas tax revenues needed for our roads, bridges, and ferry system. A road usage charge could provide a more stable source of transportation funding than the gas tax since drivers would pay by the mile instead of by the gallon. A per-mile charge more directly ties road usage to costs.
  To ensure everyone pays their fair share: Considering the range of miles per gallon (mpg) of today's vehicles on the road, the gas tax has become inequitable. For the same miles driven, drivers pay widely different amounts for their roadway use depending on their vehicle's miles per gallon. This inequity is expected to grow each year as vehicle miles per gallon continues to increase.
- **Will this be an additional tax?**
  No, the road usage charge is being considered as a replacement to the gas tax, not in addition to the gas tax. On your summary of charges, you will notice that we have estimated the amount paid in gas tax based on your vehicle's miles per gallon and reported mileage. This amount has been deducted from your final road usage charge amount to avoid double payment.
- **What is this simulation exploring?**
  This road usage charge simulation is a small-scale, short-term study that gives Washing-ton drivers a chance to experience different approaches to road usage charging. This re-search simulation also gives drivers an idea of how a real system could work and provides an opportunity to share their feedback. Decision makers will use this feedback to understand the pros and cons of this approach to funding our transportation system statewide.
- **What happens if I drive out of state or in private roads?**
  If a road usage charge system is put in place, the Legislature must decide whether and how to allow Washington drivers to avoid paying for miles they drive out of state or off public roads. One way is to allow a standard exemption for all drivers. Another way is to allow drivers to claim exemptions for miles driven out of state or off public roads. You can choose this option as part of the simulation. A third way, tested in previous research in Washington, is to allow drivers to choose a location-enabled mileage reporting technology that can automatically deduct miles driven out of state or off public roads from the amount they owe.
- **Can miles be reported without using GPS data?**
  Yes. Participants can select "Self-Reporting". This option requires participants to report their vehicle's odometer reading via a web-based account system. The odometer reading approach does not require any technology or GPS to utilize.
- **Do participants in this pilot project have to pay with their own (real) money?**
  No. Participants are not required to pay real money. However, certain participants may be eligible for follow-on research as part of this research. Those who volunteer to participate in the extended research, if selected by the re-search team, may receive pre-paid debit cards with sufficient funds to pay simulated road us-age charge payments.

- **How would out-of-state drivers be handled in a road usage charge system in Washington state?**
  If a road usage charge system is put in place in the future, the gas tax will likely need to stay in place while the state slowly transitions away from it. During this time, drivers would only pay the road usage charge or the gas tax, but not both. As long as the gas tax stays in place, out-of-state drivers would continue to pay the gas tax at the pump, just like they do today. Once the gas tax is fully retired, decision makers will need to determine how they will collect the tax from out-of-state drivers based upon the technology and systems available at that time.
- **Have other states adopted a road usage charge?**
  Utah, Oregon, and Virginia are the three states with currently operating programs. About a dozen states are exploring and developing their own programs.

3.5 Program Rewards

Participants accrued up to $100 for participating in the AutoPilot follow-on experience based on the following criteria:

- Participants accrued $10 for signing the participant agreement and providing their vehicle identification number (VIN)
- If the vehicle was eligible, participants accrued $25 in WA RUC Program Rewards each month they opened their mock invoices, submitted their odometer reading, and responded to a quick survey, for an additional total of up to $75.
- Participants accrued $15 in WA RUC Program Rewards after completing a 10-minute survey when the program ended.

4.0 AUTOPILOT DEMOGRAPHICS AND OPERATIONAL SUMMARY

About 10% (51 of 492) of Simulation participants expressed interest in the AutoPilot follow-on experience. However, of these 51 vehicles, only 32 were eligible based on vehicle make and model and signed the participant agreement. Of these 32 vehicles, 27 completed the enrollment process to participate in AutoPilot. Of these, 23 completed the follow-on experience. In addition, the project team recruited an additional two participating vehicles for a total of 25 complete vehicles.

The majority of eligible vehicles for telematics were Teslas. In line with Tesla owner demographics, AutoPilot participant demographics skewed male and higher income: 84% of participants identified as male, 41% had household incomes over $150,000, 25% had incomes between $100,000 and $150,000), 65% reported working full time, and 81% reported education levels of a bachelor's degree or higher.

Data collected during the AutoPilot follow-on experience are summarized below in Table 1.

Table 1: Summary of Data Collected in AutoPilot

Monthly metric	Low	High	Average
Number of miles driven	78	3,222	815
Number of miles driven out of state	0	2,543	131
% of drivers with out of state miles recorded	32%	44%	40%
Gas tax credit	$0	$8.68	$8.09
Net RUC due	$1.86	$38.92	$15.85

5.0 SURVEY RESULTS

A total of 19 participants out of 25 (or 79%) took part in the online survey at the end of the experience. The main survey results are described here.

- 79 percent of respondents rated the process of enrolling the vehicle in the AutoPilot follow-on experience as 'Very Easy'. Only one responded, 'Somewhat difficult'.
- Most participants (17 out of 19) selected 'Convenience' when asked why they chose to opt into AutoPilot instead of other mileage reporting options (e.g., self-reporting, smartphone apps, and plug-in devices). The next two best choices for choosing telematics was 'Interest in helping the state explore this technology' and 'Curiosity about how telematics technology works' respectively.
- Most participants (15 out of 19) did not experience any technical issues with telematics mileage reporting during the AutoPilot follow-on experience. Three respondents said they were not sure.
- When participants were asked if they found the summary on the invoices relevant to understanding road usage charges, most participants (15 out of 19) responded 'Strongly Agree'. Three participants responded, 'Somewhat Agree' and only one responded 'Somewhat Disagree'.
- Most participants (16 out of 19) thought the mock invoices were easy to understand; two responded 'Somewhat Agree', and one participant did not find the invoice easy to understand.
- Most participants (14 out of 19) found the FAQs in the mock invoice useful to enhance their understanding about a RUC program. Three participants did not read the FAQs.
- Most participants (16 out of 19) responded they trust the miles driven and the road usage charges indicated on the mock invoices. Three participants did not trust the miles driven and the RUC charges. One participant claimed that on the second invoice, miles were recorded for out-of-state travel (for a couple of miles), but the participant claims the vehicle was not out of state for the entire month. The other two participants did not explain.
- The preferred method for receiving invoice reminders is still via email (16 out of 19) rather than text message.
- When asked about the invoice's most useful information, three overarching themes consistently emerged and are categorized in order of frequency as follows:
    - Miles driven in-state versus out-of-state
    - Miles driven and charges per mile
    - Reconciliation between estimated gas tax paid and RUC due
- When asked about the invoice's least useful information, responses were very limited. However, a few comments shed light on information that could be useful to incorporate or revisit in future studies to enhance clarity, credibility, and trustworthiness:
    - Include the before and after odometer read based on the baseline odometer information provided to gain more confidence on miles driven.
    - Two participants suggested improving the clarity of actual miles driven, particularly when it comes to out-of-state travel. The participants voiced their concerns regarding the

precision of out-of-state mileage calculations had they have driven across state borders. One of the participants expressed a desire to have the ability to reconcile miles driven with their own personal travel records to ensure accuracy.

- The start and end dates were not very clear.
- Make clear if the invoice is an annual bill or a monthly bill.

- The following responses were received when asked to provide any additional feedback about the overall experience with AutoPilot:
  - “Cool! I hope this leads to lower registration costs for EVs”
  - “It would be great if a future RUC would also include some way of recording miles driven by vehicles with studded tires since those things chew up the roadway more than semis.”
  - “Thank you for this opportunity to participate”.
  - “I would like to have a better understanding of how much of the expenses of road construction and maintenance and ferries are paid for by the road users, how much by the general taxpayers.”
  - “Paying for actual road usage is more fair than everyone paying the same fuel tax.”

6.0 LESSONS LEARNED

The AutoPilot follow-on experience demonstrated that it is technically feasible to comply with a RUC program by collecting accurate mileage data from in-vehicle telematics, both directly from an OEM and from a third-party aggregator. While it is technically feasible, this section identifies some challenges and lessons learned that emerged from the experience.

- **Vehicle eligibility remains a challenge.** Vehicle eligibility remains a challenge, particularly when it comes to vehicles manufactured prior to 2022. The hurdle lies in the fact that older vehicles are not equipped with the necessary hardware or software to meet the connectivity requirements to transmit vehicle data. Factory-fitted telematics units are technological platforms that allow for the retrieval and transmission of vehicle data from an automobile's onboard computer. These factory-embedded units collect and transmit vehicle data including location, odometer readings, fuel levels, and other vehicle data. The data is then communicated to a centralized server via a cellular network. Vehicles must have both the hardware and software for telematics, and the latter must be enabled by the driver (which can sometimes include an additional fee). Once the data is stored on the server, it can be accessed by the OEM and is often reflected to the user through an app or website with a vehicle-specific login. As technologies advance and support for outdated equipment is discontinued, vehicle eligibility may alter. For instance, the functionalities and connectivity of older vehicles equipped with 3G telematic modems were affected as support for 3G networks was discontinued to support newer 4G and 5G technologies.
- **Neglecting software updates can prevent vehicle eligibility.** Software updates for telematics may be made by the OEM (which may occur due to a variety of considerations), but the user has not yet accepted relevant over-the-air (OTA) updates and/or may not be paying for telematics data.
- **The evolution of wireless cellular networks brings forth challenges that impact vehicle connectivity.** The transition from 3G to 5G introduced a fundamental change in network infrastructure, creating compatibility issues as advanced networks emerged. A concern moving forward is the potential obsolescence of telematics software and hardware in vehicles if they are designed to function within the limitations of currently available networks.
- **Vehicle eligibility can be inconsistent across makes, models, trims, and years within the same manufacturer.** The pilot study revealed that eligibility for vehicles varies, even within the same manufacturer. It is crucial to work with OEMs in advance to ascertain precise eligibility and choose makes, models, and years for participation that have consistent eligibility.
- **Telematics data directly from OEM yielded a more seamless and data-rich experience.** Gathering data directly from the OEM proved to be a more seamless process, free from the connectivity issues encountered when relying on a third-party aggregator.
- **The attainment of optimal precision levels may be impeded by third-party aggregators.** High precision is warranted for RUC, especially when miles exemptions, out-of-state miles, and private road credits are to be offered. The third-party aggregator used for the AutoPilot experience recommended that their data be accessed less frequently, usually once every 30-60 minutes and never more frequently than every five minutes. The reason is that accessing data requires pinging the vehicle, rather than pulling data from a centralized server, and that can drain battery levels and result in a mile range loss. The approach used with the third-party

aggregator is not a viable data-gathering process for assessments that require detailed location information, such as whether a vehicle is located on a public or private road. To rectify this limitation, one viable approach is to establish a geofence around specific geographical boundaries, such as state lines, and ping the vehicle more frequently when it is within this geofence.

- **The third-party aggregator approach presented a higher degree of technical intricacies and costs compared to direct engagement with the OEM.** Several points of friction in maintaining data access through a third party were encountered, namely issues with API tokens changing throughout the pilot as well as limits on the volume of data accessed per vehicle per month that were not increased as necessary for the pilot. Additionally, access through a third party allows access to a participant's entire telematics account with an OEM, which may include multiple vehicles from that manufacturer. To make sure that the right vehicle's data is used for RUC, participants must furnish supplementary information, such as odometer readings, to properly match the vehicle in question. In addition, at this time, third-party aggregators represent a higher cost than direct OEM engagement; however, this is not indicative of the future relative costs of these two approaches. In the future, third-party aggregators may represent a more economical approach as they can source data across a wide range of OEMs, handling the analysis and reduction to minimal data needed for RUC purposes more efficiently. With volume-based contracts, per-unit costs in a small-scale pilot are relatively high but can be negotiated to more reasonable levels in a large-scale program.
- **There is an opportunity to improve the invoice layout by including more information about the odometer mileage for the billing period.** Participants were asked to complete a brief questionnaire for each billing cycle. A few participants suggested including the beginning and ending odometer readings on the invoice to better assess whether the miles driven look accurate. A few participants were also unsure of the format that was used to inform the RUC period. It was suggested to specify the 'start' and 'end' dates for the RUC period.
- **While the FAQs did help improve comprehension of RUC, there were still lingering questions that remained unclear.** Participants were asked to complete a brief questionnaire for each billing cycle. When were participants invited to share any questions for the research team that were not addressed in the FAQs, the following emerged:
    - "Will the road usage charge replace the EV fee that I see in my car registration?"
    - "Could this fee be paid annually rather than monthly?"

The AutoPilot experience revealed the challenges and opportunities for embedded telematics as part of a future RUC program. Today, several configurations exist for accessing embedded telematics to support a RUC program as explained below. All of these configurations depend on an opt-in framework, that is, customers must have the choice whether to opt in to use OEM platforms as the basis for reporting and/or paying RUC.

- **Indirect access to OEM data off the vehicle by a third-party data aggregator and collection by a third-party account manager.** This approach has been tested several times including in California (2016-2017) and in AutoPilot, as well as in live programs in Oregon, Utah, and Virginia. This approach is costly at small volumes but offers opportunities for lower costs of collection at scale. Perhaps more importantly, this approach requires a greater degree of data transmission, which increases cost and introduces some challenges for performance, such as

the inability to reliably measure miles driven by location for customers who prefer that degree of precision.

- **Direct access to OEM data off the vehicle by a third-party data aggregator and collection by a third-party account manager.** AutoPilot was the first pilot to test this approach in the U.S. It represents a less costly arrangement in that the necessary vehicle data to compute RUC including location-based exemptions are accessible directly from the OEM, reducing the amount of data transmission and direct vehicle interaction required. This represents an improvement over the indirect access approach tested to date in terms of both cost and performance, and it shows promise for cost-effective telematics-based RUC at scale.
- **Direct computation of RUC on the vehicle and collection of charges by a third-party application developer acting as an account manager.** Not yet tested, this approach involved "edge computing," which means using software installed in vehicles to calculate RUC due. Under this scenario, location data would never leave the vehicle: only the amount of RUC owed by time frame (and potentially by jurisdiction) and other essential data such as VIN, could be transmitted to an account manager. This approach represents an opportunity for even lower costs for using telematics as the basis for computing RUC.
- **Direct computation and collection of RUC from customers by an OEM acting as an account manager.** In 2020, Ford illustrated a concept for how its vehicles could measure and compute RUC and collect the fee in vehicle, with the OEM acting as a full-service account manager. This approach remains conceptual and has not been tested. For interested customers, this approach could represent a lower-cost and high-performance possibility for using telematics not just to report but also to pay RUC.

The AutoPilot experience demonstrated the technical feasibility of using embedded telematics to compute RUC for individuals, both directly from an OEM and from a third-party aggregator (the top two scenarios listed above). While vehicle eligibility remains a challenge since older vehicles are not all equipped with the necessary hardware or software to meet the connectivity requirements to transmit vehicle data, the limited number of vehicles proved that it is technically feasible to comply with a RUC program by collecting accurate mileage data from in-vehicle telematics. Data gathered directly from the OEM proved to be a more seamless process, free from connectivity issues encountered when relying on third-party aggregator data, and lower cost. When precision is required, especially when miles exemptions, out-of-state miles, and private road credits are to be offered, data obtained directly from the OEM is more appropriate as it is more granular and more comprehensive.

The two approaches tested in AutoPilot represent an advance for telematics-based RUC in that they show a progression from indirect to direct access. Further research and engagement with automotive partners can explore opportunities to scale these approaches, improve their performance while controlling costs, and consider moving toward edge computing and engaging OEMs as CAMs as two prospective emerging approaches for further cost reduction and performance improvement.