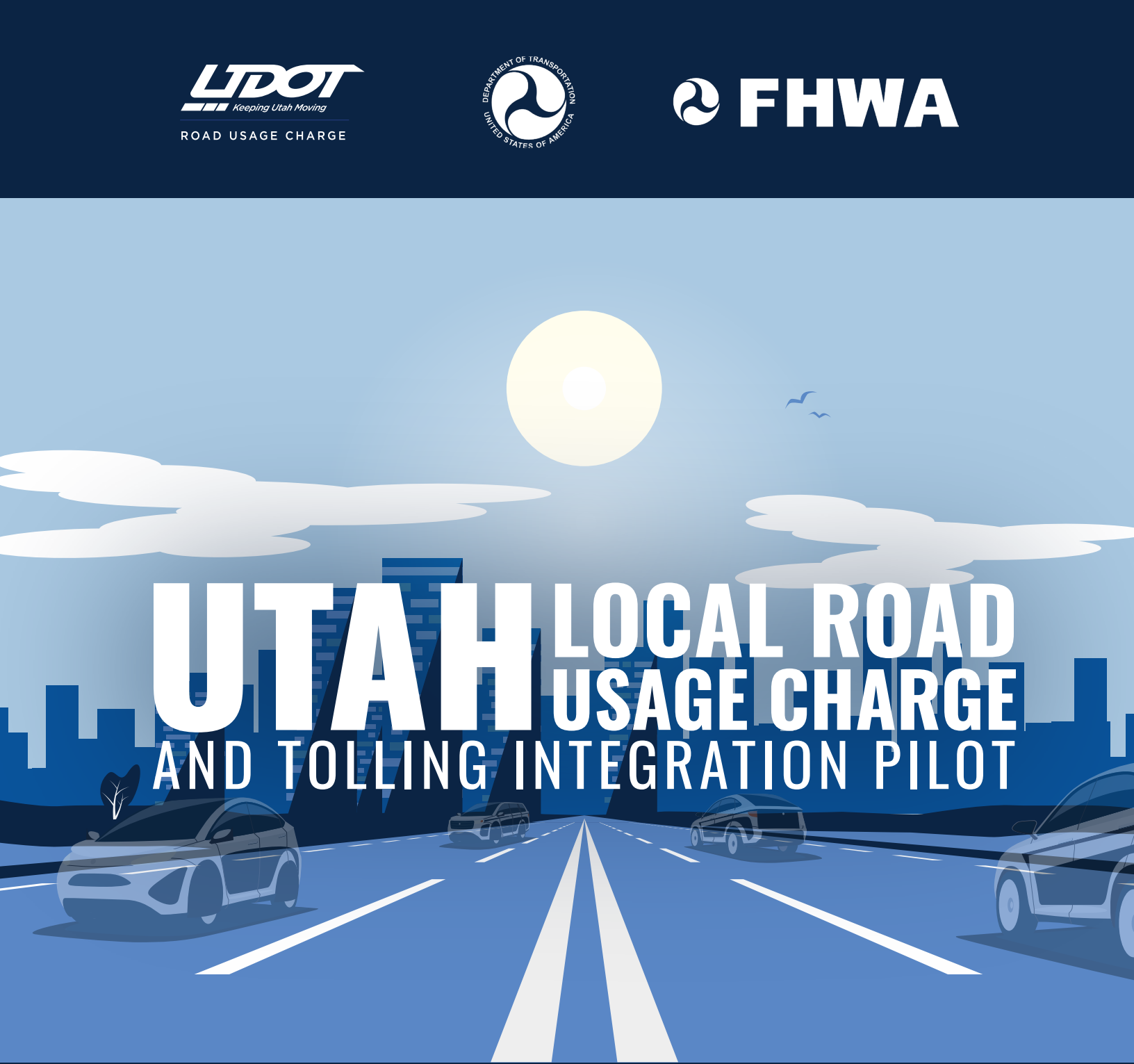




UTAH LOCAL ROAD USAGE CHARGE AND TOLLING INTEGRATION PILOT

FINAL REPORT

JUNE 2025

PREPARED BY:

Utah Department of Transportation

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APPENDICES

Appendix A: Verra Mobility Connected Vehicle Pilot Final Report

Appendix B: Participant Surveys

ACRONYMS AND ABBREVIATIONS

ALRS Advanced Linear Referencing System

CAM Commercial Account Manager

CSR Customer Service Representative

BRD Business Rules Document

E2E End-to-End

FAQ Frequently Asked Questions

FHWA Federal Highway Administration

FY Fiscal Year

GPS Global Positioning System

GNSS Global Navigation Satellite System

HPMS Highway Performance Monitoring System

HOV High Occupancy Vehicle

ACRONYMS AND ABBREVIATIONS (CONT.)

ICD	Interface Control Document
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MRD	Mileage Reporting Device
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OBD-II	Second-generation Onboard Diagnostics
---------------	---------------------------------------

OEM	Original Equipment Manufacturers
------------	----------------------------------

RFP	Request for Proposal
------------	----------------------

RUC	Road Usage Charge
------------	-------------------

SRS	System Requirements Specifications
------------	------------------------------------

STSFA	Surface Transportation System Funding Alternative
--------------	---

UDOT	Utah Department of Transportation
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VIN	Vehicle Identification Number
------------	-------------------------------

VMT	Vehicle Miles Traveled
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EXECUTIVE SUMMARY

In 2019, the Utah Department of Transportation (UDOT) was awarded two Surface Transportation System Funding Alternative (STSFA) Round 4 federal grants. The first, the Integration of Road Usage Charge (RUC) and Express Lanes Tolling grant, was to look at the ability to combine elements from the Utah Road Usage Charge Program for alternative fuel vehicles and the UDOT Express Lanes program to reduce administrative costs and improve the overall user experience. A second grant, the RUC Local Overlay grant, was awarded to explore the concept of local governments being able to add local overlay zones to the Utah Road Usage Charge Program within their jurisdiction. Because of the overlap in various aspects of these two grants and similar participants, UDOT and the Federal Highway Administration (FHWA) agreed to combine these two grants into a single pilot. The new combined pilot is called the Utah Local RUC and Tolling Integration Pilot (the pilot).

The primary goals of the pilot were to test the feasibility of streamlining the process of charges for state RUC miles, local RUC miles, and Express Lanes Tolling, reducing administrative costs and enhancing customer experience. A secondary objective was to test the accuracy of RUC mileage reporting technology to determine toll charges in Express Lanes and mileage for state and local RUC.



PILOT OVERVIEW

Four Utah cities (Ogden, South Jordan, Saratoga Springs, and St. George) partnered with UDOT for the pilot to help with the RUC Local Overlay testing. **Table ES-1** provides the RUC rates used in the pilot for both state RUC and local RUC (miles driven on city-maintained roads within the four city limits).



Table ES-1. RUC Rates Used for the Pilot

	Per-Mile RUC Rate
Ogden	\$0.0060
Saratoga Springs	\$0.0070
South Jordan	\$0.0050
St. George	\$0.0040
State RUC	\$0.0100

A private sector commercial account manager (CAM), ETAN Industries, Inc. (ETAN), was selected for the pilot and was responsible for setting up participants' pilot accounts, distributing mileage reporting devices (MRDs) for collecting mileage data, processing mileage and toll charges (simulated only), issuing statements, and providing customer support during the six-month pilot. The pilot collected toll and mileage information through 2 primary means:

1

Geotab GPS plug-in Mileage Reporting Device that plugs into the vehicle to collect trip data with mileage and location of trips to assess accurate simulated RUC on both local and state roads;

2

Toll transactions were collected through an interface with the Express Lanes' Back-Office system that detects the use of Express Lanes through use of transponders mounted on the windshield.

The CAM was responsible for developing a statement combining all simulated charges associated with Express Lanes, state RUC and RUC Local Overlay for a given month. These statements were distributed monthly over the course of the six-month pilot (October 2023 – March 2024) and included the total for each type of charge. More detailed information on the monthly charges and individual trips and transactions was available to participants through the web portal.

In participants' online accounts all charges were deducted from a single, combined, simulated electronic wallet, triggering automatic fund replenishments in accordance with a predefined minimum threshold. In order to test for parameters like optimal initial balance, minimum threshold, and replenishment amount, three different sets of values were tested for different participants (**Table ES-2**).

Table ES-2. Simulated Wallet Parameters

Parameter	Set 1	Set 2	Set 3
Initial Simulated Wallet Balance	\$25	\$40	\$50
Minimum Balance Threshold	\$10	\$15	\$20
Automatic Replenishment	\$15	\$25	\$30

RECRUITMENT

The Utah Local RUC and Tolling Integration Pilot aimed to recruit 100-120 participants. To help meet the goals of the pilot, UDOT focused on recruiting Utah citizens who use the Express Lanes and/or are residents of the four cities. To encourage participation, UDOT offered incentives in the form of a \$100 digital Amazon gift card and free use of the I-15 Express Lanes during the pilot. Utah government employees were not eligible to receive the gift card but could use the Express Lanes for free during the pilot.

UDOT and the CAM maintained a recruitment database that included those selected and invited to participate in the pilot, those who completed enrollment, and those who were active or had plugged in their MRD and were reporting mileage. **Table ES-3** presents the actual recruitment results against the targets. The total recruits only include the 112 who activated the MRD and reported mileage data; it does not include the 7 participants who didn't complete their device activation.

Table ES-3. Recruitment Targets vs. Actual Recruitment Results

	Express Lanes Account Holders		Non-Express Lanes Account Holders		TOTAL	
	Target	Actual	Target	Actual	Target	Actual
Ogden	15-20	36	<5	2	20-25	35
St. George	<5	0	15-20	4	20-25	4
Saratoga Springs	15-20	18	<5	4	20-25	22
South Jordan	15-20	25	<5	3	20-25	26
Other*	15-20	18	0	2	20	20
TOTAL	60-85	97	15-35	15	100-120	112

* Includes UDOT staff



PILOT OPERATIONS

The Utah Local RUC and Tolling Integration Pilot launched on October 2, 2023, and ran for six months concluding on March 31, 2024. A total of 119 participants enrolled in the pilot with 112 activating their MRD (plugged in their device and were reporting mileage). Of the 112 who activated, 5 participants dropped out of the pilot shortly after joining, resulting in a total of 107 participants completing the six month pilot. Over the six months, the 107 active participants drove a total of 655,378 miles with 44,522 miles driven within the four participating cities (**Figure ES-1**).

Figure ES-1. Utah Local RUC and Tolling Integration Pilot Statistics

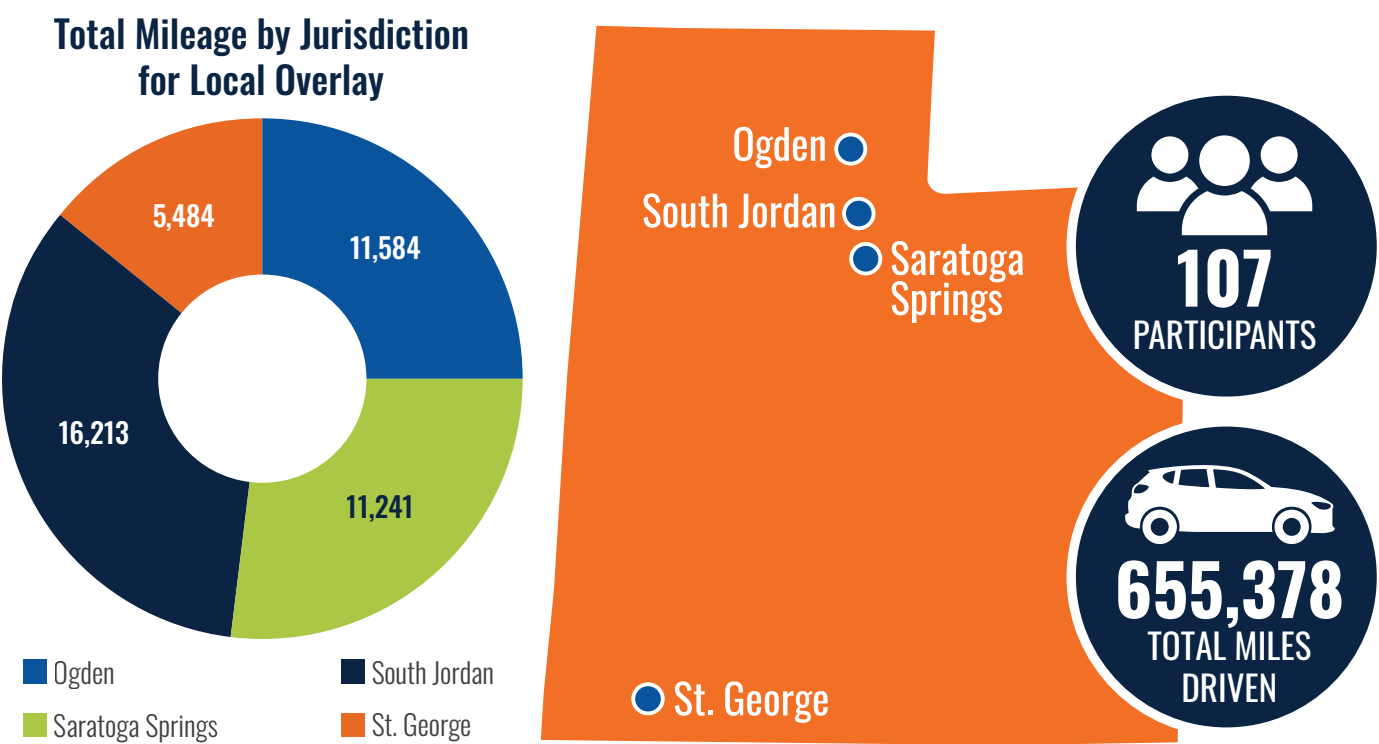


Table ES-4 provides the total revenues “collected” (all charges were simulated; no real money was collected) for tolls, state RUC and local RUC over the six-month pilot.

Table ES-4. Total Revenues by Method

Revenue Method	Revenue
Tolls	\$9,053.00
State RUC	\$6,551.92
Local RUC	\$251.18
TOTAL REVENUE	\$15,856.10

PARTICIPANT SURVEYS

To gather feedback about the pilot experience, pilot participants were invited to complete two online surveys:

- **Initial Survey:** This survey was sent out to participants after they completed their enrollment in the pilot, received their MRD and activated the MRD (successfully reporting mileage).
- **Post-Pilot Survey:** This survey was sent out to all participants on the same date, April 8, 2024, one week after the Utah Local RUC and Tolling Integration Pilot concluded.

The initial survey received had an 89% response rate, and the post-pilot survey had an 82% response rate. At the conclusion of the pilot, 65% of participants reported that their understanding of an RUC increased due to the pilot. Additionally, nearly 8 in 10 participants believed it is fair or very fair for cities to implement a local RUC. Furthermore, the preference for a combined tolling and RUC statement increased significantly, from about 70% before the pilot to approximately 90% after.



PILOT FINDINGS

The Utah Local RUC and Tolling Integration Pilot met the goals and objectives for integrating RUC with Express Lanes Tolling and demonstrating RUC Local Overlay.

The integration of RUC with Express Lanes Tolling demonstrated several important lessons. First, integrating tolling and RUC into a single web portal and monthly statement was successful, providing a positive user experience. However, the CAM was unable to modify the statement to include transaction level information for Express Lane usage and starting and ending wallet balances due to the limitation of the system provided for the pilot. The shared wallet system, where both tolling and RUC charges are deducted from one account, functioned well, and three wallet tiers were successfully simulated. However, automated tolling using the Geotab GPS plug-in device was found to be infeasible due to accuracy issues. Additional issues with the MRD that affected the users' experience included bulky devices, low stability of the plugged-in device for some users, battery drainage issues, and compatibility problems with certain vehicles.

The pilot also demonstrated that RUC Local Overlay could be accurately assessed across the four cities, and that the GPS-enabled MRD could collect mileage data and distinguish travel in different local jurisdictions. The mileage and location data could be used to:



Assess RUC with different rates in each local jurisdiction

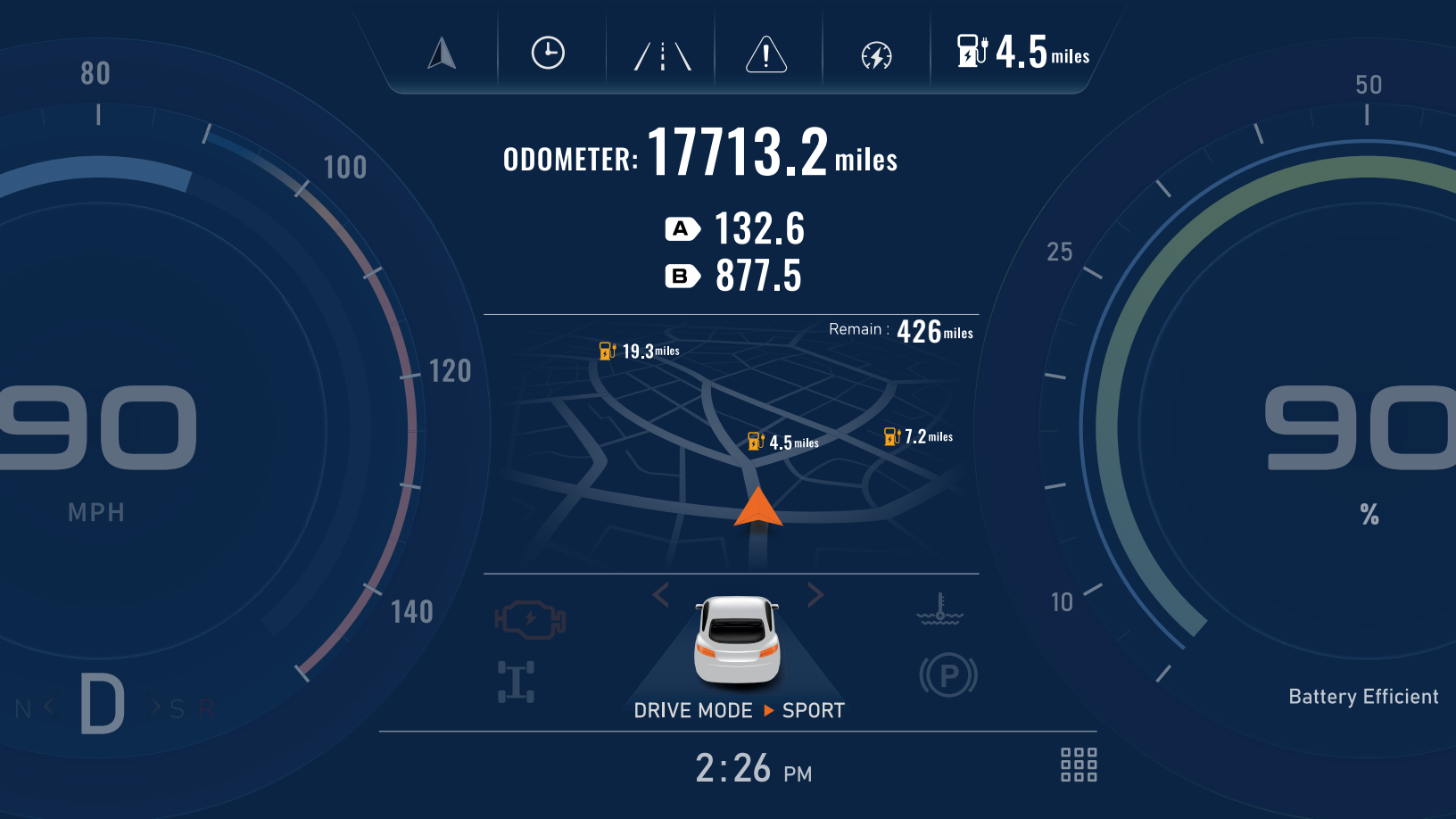


Report RUC charges by local jurisdictions



SECTION 1.0

INTRODUCTION



1.0 INTRODUCTION

The Utah Department of Transportation (UDOT) is currently operating a road usage charge (RUC) program for the state that allows eligible vehicle owners to pay a per-mile fee in lieu of paying their annual alternative fuel fee at the time of registration. This RUC program launched January 1, 2020, and as of July 2024 has over 4,500 vehicles enrolled. In an effort to improve Utah's current RUC program, UDOT applied for a federal grant to explore simplifying and improving the driver payment experience and reduce costs for payment collection.

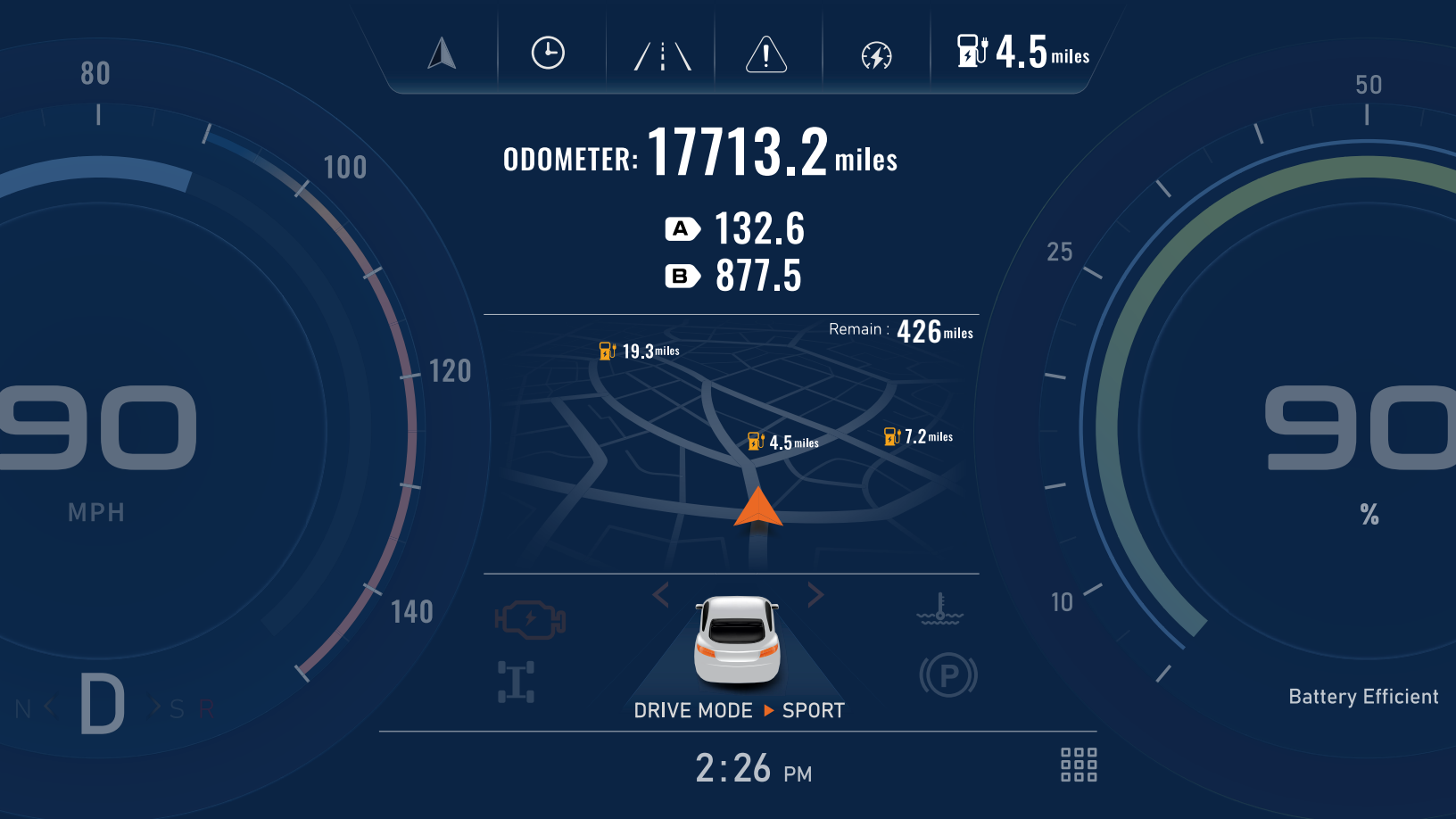
In 2019, UDOT was awarded two Surface Transportation System Funding Alternative (STSFA) Round 4 federal grants. The first, the Integration of Road Usage Charge and Express Lanes Tolling grant, was to look at the ability to combine elements from the Utah Road Usage Charge Program for alternative fuel vehicles and the UDOT Express Lanes program to reduce administrative costs and improve the overall user experience. A second grant, the RUC Local Overlay grant, was awarded to explore the concept of local governments being able to add local overlay zones to the Utah Road Usage Charge Program within their jurisdiction. Because of the overlap in various aspects of these two grants and similar participants, UDOT and FHWA agreed to combine these two grants into a single pilot. The new combined pilot is called the Utah Local RUC and Tolling Integration Pilot (the pilot).

This report provides a summary of the work completed and the findings from the Utah Local RUC and Tolling Integration Pilot. Section 2 provides an overview of the pilot including a discussion of how the pilot was developed and the results of the testing conducted prior to the pilot launch. Section 3 discusses the pilot recruitment efforts. Section 4 provides the results from the pilot operations. Section 5 discusses the results from the participant surveys, which included an initial survey at the beginning of the pilot and a post-pilot survey conducted at the conclusion of the pilot. Finally, Section 6 provides the pilot findings including lessons learned and recommendations.



SECTION 2.0

UTAH LOCAL ROAD USAGE CHARGE & TOLLING INTEGRATION PILOT OVERVIEW



2.0 UTAH LOCAL ROAD USAGE CHARGE & TOLLING INTEGRATION PILOT OVERVIEW

The Utah Local RUC and Tolling Integration Pilot evaluated the integration of RUC with Express Lanes Tolling as well as the feasibility of charging a supplement to the state RUC for the use of local roads in four Utah cities: Ogden, South Jordan, Saratoga Springs, and St. George. UDOT wanted to test the feasibility of streamlining the process of charges for state RUC miles, local RUC miles, and Express Lanes Tolling, reducing administrative costs, and enhancing the customer experience.

2.1 PILOT GOALS AND OBJECTIVES

There were two primary goals of the Local RUC and Tolling Integration Pilot and three objectives tied to each of these goals. These include:



GOAL 1: Demonstrate the Integration of RUC with Express Lanes Tolling



Objective A: Demonstrate a combined tolling and RUC web portal and combined tolling and RUC monthly statements—show that both tolling and RUC charges can be displayed to users on a single web portal and on combined monthly statements.



Objective B: Demonstrate a combined tolling and RUC simulated wallet, a single electronic storage of simulated funds from which RUC and tolling transactions can be made. Show that both tolling and RUC charges can be deducted from a single electronic simulated wallet, and explore appropriate values for funding the simulated wallet.



Objective C: Determine what elements are necessary for automated tolling using RUC mileage reporting options (location reporting with lane determination to a specific degree of accuracy and enforcement paradigm changes).



Goal 2: Demonstrate RUC Local Overlay



Objective A: Work with localities to determine an RUC Local Overlay rate for each locality for the pilot, a very rough approximation for the amount that would cover the cost of the maintenance of locally maintained roadways if 100% of light vehicles were paying RUC.



Objective B: Demonstrate the data collection and mapping needs (if any) to apply RUC Local Overlay Charging (location data indicating use of locally maintained roads in a given jurisdiction).

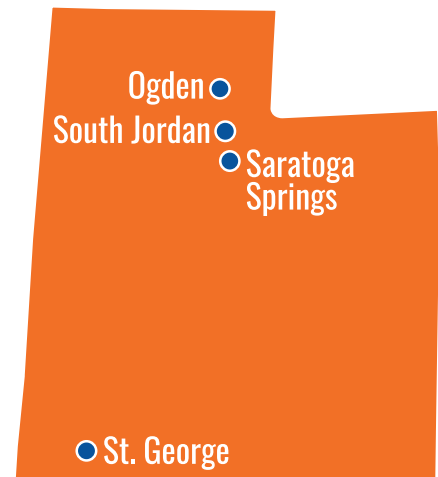


Objective C: Establish RUC partnerships with local government agencies and demonstrate the application of RUC Local Overlay charges based on data.

2.2 PILOT OVERVIEW

The Utah Local RUC and Tolling Integration Pilot was designed to evaluate the integration of State RUC, Express Lanes Tolling, and local RUC at an operational level. The pilot tested the feasibility of a single account with a combined wallet for the user to manage their three charges, as well as a single device that could detect and report tolling, State RUC and local RUC.

Tolling transactions were reported to the pilot system through integration with the Express Lanes.



Four Utah cities (Ogden, South Jordan, Saratoga Springs, and St. George) partnered with UDOT for the pilot, in particular, to help with the local RUC overlay testing including rate setting unique to each city and recruitment of participants within their jurisdiction. Four local RUC zones (or overlays) were defined for the pilot, covering each of the participating cities' boundaries. Miles driven on all city-maintained roads within each city limit would be charged the appropriate local RUC rate. State-maintained roads within the four city zones would not be charged the local RUC rate, only the Utah state RUC rate, the rate in the existing RUC program at the time the pilot launched. The rates are discussed in more detail in Section 2.2.2.

2.2.1 COORDINATION WITH LOCAL JURISDICTIONS

During the planning phase of the pilot, UDOT met with representatives from the four participating cities. In all cases, initial contact was made with the City managers. In Ogden and Saratoga Springs, subsequent meetings were held with the City managers. In South Jordan and St. George, meetings were held with public department heads who were delegated by the respective City managers. At these meetings, UDOT presented general road usage charge concept information and then provided details about the Utah Local RUC and Tolling Integration Pilot. Meeting participants understood that although none of the jurisdictions currently have local fuel taxes to generate revenue, this pilot was to test the operational feasibility should a local tax or fee be assessed in the future. The agencies were generally in favor of the pilot and agreed to distribute the information about the pilot to their employees and seek their participation in the pilot. UDOT kept in touch with the representatives from the four cities over the course of the pilot. The local rate setting methodology discussed in Section 2.2.2 was distributed to local jurisdictions as well.

2.2.2 RATE SETTING

The state RUC rate used in UDOT's operational RUC program was applied in the pilot. The pilot also applied local RUC rates for each of the four partner cities. The local RUC rates were individually determined using data provided by the participating cities. The goal of local RUC rates was to roughly recover the total of maintaining the local roads, which was roughly calculated as the total cost of maintaining the local roads divided by the total number of vehicle miles traveled (VMT) on those roads.

The local RUC rates, expressed in \$/mile, were estimated using annual Class B&C road funding for each city. Local VMT within each city (miles) was estimated using data from UDOT's annual Highway Performance Monitoring System (HPMS) report. Class B&C roads consist of all public roads that are not state or federal roads. Class B&C funding was established by the state legislature as a means of providing assistance to localities for designing, constructing, and maintaining eligible class B&C roads.

Table 1 shows the Fiscal Year (FY) 2021 B&C road funding for the four partner cities.

The VMT on locally-maintained roadways for each city was estimated based on 2021 VMT estimates provided by UDOT's Transportation Performance Management Division for each of the partner cities, shown in **Table 2**.

There are two VMT estimates stemming from two section length totals: B&C and Advanced Linear Referencing System (ALRS). The section lengths reported for B&C mileage originate from UDOT's annual HPMS report to FHWA. The ALRS road sections are accurately based on digitized road sections for a portion of the locally-maintained roadways in each city. Further, UDOT conducts traffic counts on a sampling of these roadways on a three-year cycle. For this reason, the estimated VMT for the ALRS sections is considered a more valid source for estimating VMT but represents only a fraction of the road mileage in each city, shown in the last column of **Table 2**.

Table 1. 2021 FY B&C Funds Allocated to Four Utah Cities

City/Town	B&C Funds 2021 FY Allocation
Ogden	\$3,657,653
Saratoga Springs	\$1,363,357
South Jordan	\$3,109,754
St. George	\$4,123,568

Table 2. 2021 VMT Estimates from Two Sources, Four Utah Cities

City/Town	System	Section Length (mi)	Annual VMT in 2021	ALRS % of Total Road Mileage
Ogden	B&C	262.907	155,947,494	18%
	ALRS	56.093	95,402,388	
Saratoga Springs	B&C	106.838	3,551,055	14%
	ALRS	17.162	28,447,725	
South Jordan	B&C	272.471	102,605,154	22%
	ALRS	44.359	113,760,008	
St. George	B&C	344.915	314,320,608	22%
	ALRS	98.775	433,689,010	

Applying this fraction to the B&C funding yields an estimate of the amount of those funds that could be allocated to ALRS sections. The resulting estimated local RUC rate for each city is shown in **Table 3**. All RUC mileage driven outside of the local overlay zones, or on state-maintained roads within the zones, was charged at the state RUC rate (referred to as base RUC charges on statements) at the time the pilot launched, which was \$0.01/mile.

Local RUC Rates Calculated as:

Total Cost to Maintain Local Roads

÷

Vehicle Miles Traveled on Local Roads

Table 3. RUC Rates Used for the Pilot

	Per-Mile RUC Rate
Ogden	\$0.0060
Saratoga Springs	\$0.0070
South Jordan	\$0.0050
St. George	\$0.0040
State RUC	\$0.0100

2.2.3 ACCOUNT MANAGEMENT

All mileage reporting technology, mileage and toll data collection, and account management activities needed for the pilot were provided through a private sector account manager referred to as the commercial account manager (CAM). The CAM was responsible for setting up participants’ pilot accounts, distributing mileage reporting devices (MRDs) for collecting mileage and toll data, processing mileage and toll charges (simulated only; no real money was collected for the pilot), issuing statements, and providing customer support during the six-month pilot. ETAN Industries, Inc. (ETAN) was selected, through a competitive request for proposal (RFP) process, as the pilot CAM.

2.2.4 TOLL AND MILEAGE REPORTING DEVICES

The pilot collected toll and mileage information through 2 primary means:

- Geotab GO9 GPS plug-in Mileage Reporting Device that plugs into the vehicle to collect trip data with mileage and location of trips to assess accurate simulated RUC on both local and state roads;
- Toll transactions were collected through an interface with the Express Lanes’ back-office system that detects the use of Express Lanes through the use of transponders mounted on the windshield. The transponders are detected by the readers installed in the Express Lanes, which communicate information to the Express Lanes’ back-office system.



Pilot GPS Plug-in Device

2.2.5 EXPRESS LANES INTEGRATION

One of the objectives of this pilot was to test the ability of RUC mileage reporting technology to accurately determine Express Lanes usage and toll charges. This included a GPS analysis to determine if the technology provided lane-level accuracy to distinguish driving in the Express Lanes and the adjacent general-purpose lane consistently.

The CAM conducted an analysis of the selected Geotab plug-in device to determine the accuracy of Geotab GPS data in detecting Express Lane usage. This analysis revealed that the data frequency and precision of GPS points reported by Geotab were insufficient for distinguishing between different lanes on a highway. The Geotab devices record GPS data points at varied intervals, based on their proprietary algorithm. While the frequency is adequate for general route tracking, it poses significant challenges for lane-level detection. In addition, the positional data reported by Geotab is not precise enough to reliably distinguish between lanes, especially when lanes are only a few meters apart. In summary, while Geotab GPS reporting is highly effective for general route tracking, it lacks the necessary precision and data frequency to distinguish between Express Lane usage and general-purpose lane usage and, as such, cannot be used to detect Express Lane usage.

As the MRD used in the pilot could not provide lane accuracy for use of the Express Lanes, the Express Lanes vendor (who is also ETAN) was asked to provide data on Express Lanes usage for vehicles participating in the pilot (with participant permission) to the pilot system through an interface. The CAM utilized this information to process combined wallets for RUC and tolling charges for the participants as well as to provide statements that reflected both tolling and RUC charges. This information included both usage and charged tolling rates at the time of usage.

Since the Geotab GPS devices used for the pilot could not be used to detect toll usage in the Express Lanes, the project team explored if there is technology on the market that can provide this functionality and accuracy needed to collect both tolls in Express Lanes adjacent to general purpose lanes and collect mileage data for a road usage charge. The UDOT project team partnered with Verra Mobility to conduct a proof-of-concept test using telematics (utilizing Global Navigation Satellite System [GNSS] technology) with a goal to identify a toll transaction without roadside infrastructure. The details of this proof-of-concept and results are discussed in Section 4.6.



2.2.6 STATEMENTS AND SIMULATED WALLET

The CAM was responsible for developing a statement combining all simulated charges associated with Express Lanes, state RUC, and RUC Local Overlay for a given month. These statements were distributed monthly over the course of the six-month pilot and included the total for each type of charge (**Figure 1**). More detailed information on the monthly charges and individual trips and transactions was available to participants through the web portal.

Figure 1. Pilot Statement

ClearRoad Inc. 5166068722 99 wall street #1518 New York, NY 10005 US		Invoice	
		Invoice Number	#000762
		Issue Date	5 Apr 2024
		Due Date	5 Apr 2024
Bill To:		PAID \$9.77	
Ship To:			
Item	Quantity	Unit Price	Amount
Base RUC Charges	548.75	\$0.01	\$5.49
20 Mar 2024 - 5 Apr 2024			
South Jordan Local Overlay	45.68	\$0.005	\$0.23
20 Mar 2024 - 5 Apr 2024			
Toll Charges	405	\$0.01	\$4.05
20 Mar 2024 - 5 Apr 2024			
		TOTAL	\$9.77
		Payments	\$9.77
		DUE	\$0.00

In participants’ online accounts all charges were deducted from a single, combined, simulated electronic wallet, triggering automatic fund replenishments in accordance with a predefined minimum threshold. In order to test for parameters like optimal initial balance, minimum threshold, and replenishment amount, three different sets of values were tested for different participants. **Table 4** shows the three sets of parameters that were tested. Roughly a third of the participants were assigned to each set of parameters. Set 1 corresponds with amounts similar to the RUC Utah and Express Lanes simulated wallets. Set 3 doubles each parameter amount in Set 1, and Set 2 provides a middle-ground option.

Table 4. Simulated Wallet Parameters

Parameter	Set 1	Set 2	Set 3
Initial Simulated Wallet Balance	\$25	\$40	\$50
Minimum Balance Threshold	\$10	\$15	\$20
Automatic Replenishment	\$15	\$25	\$30



2.3 PILOT DESIGN AND DEVELOPMENT

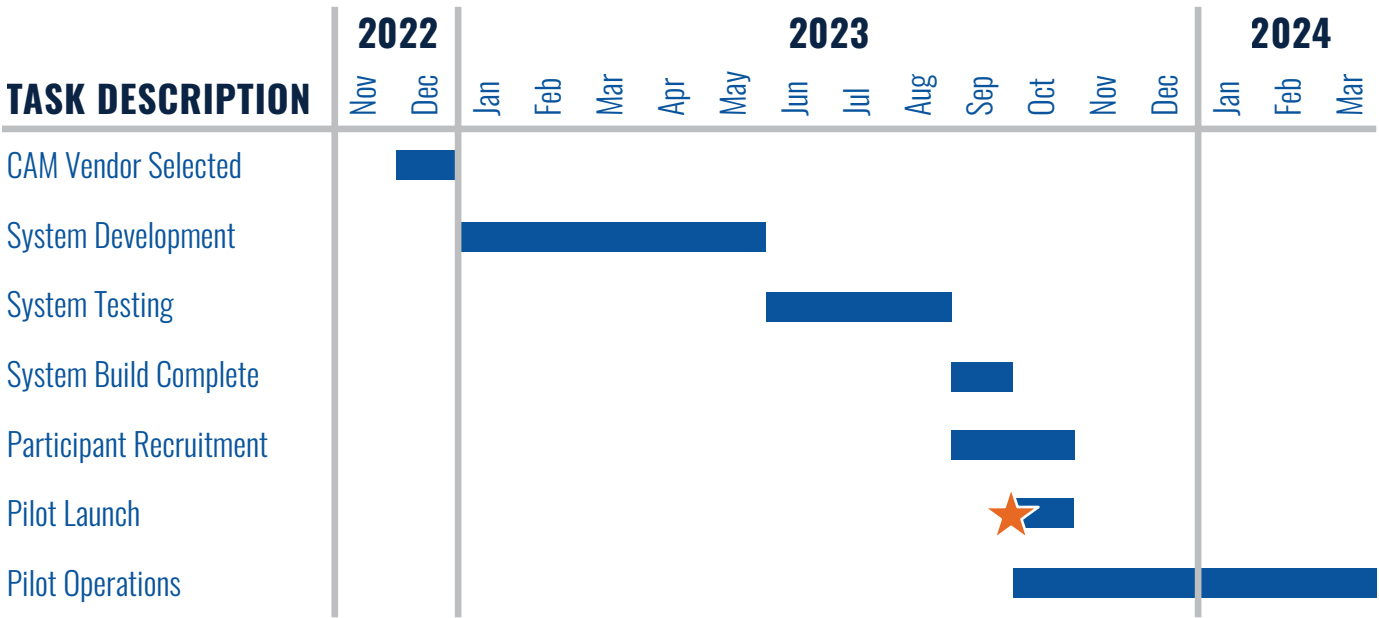
UDOT prepared detailed design and specifications including the development of requirement documents that detail what the pilot is expected to do, how the pilot system is expected to meet the objectives, and who will be doing it. These technical documents were created based on the existing requirements for UDOT’s RUC Program with changes to reflect the needs of the Local RUC and Tolling Integration Pilot.

Once the system design and specifications were complete, UDOT issued an RFP to the vendor community to provide support for all account management activities for the pilot as well as to provide mileage reporting technology. The RFP included the scope of work, project schedule, and a copy of the following documents:

- System Requirements Specifications (SRS), which provides the overall requirements the pilot system must do to meet the business and participant needs.
- Business Rules Document (BRD), which describes the business and operational requirements.
- Interface Control Document (ICD), which provides technical specifications for all system interfaces.

UDOT received seven vendor proposals, which they reviewed and evaluated against established scoring criteria, and ultimately selected ETAN with ClearRoad as the CAM to provide the MRDs and account management services for the Local RUC and Tolling Integration Pilot. Upon selection, UDOT began coordinating closely with ETAN and ClearRoad to execute system development following the schedule shown in **Figure 2**.

Figure 2. Pilot Development Schedule

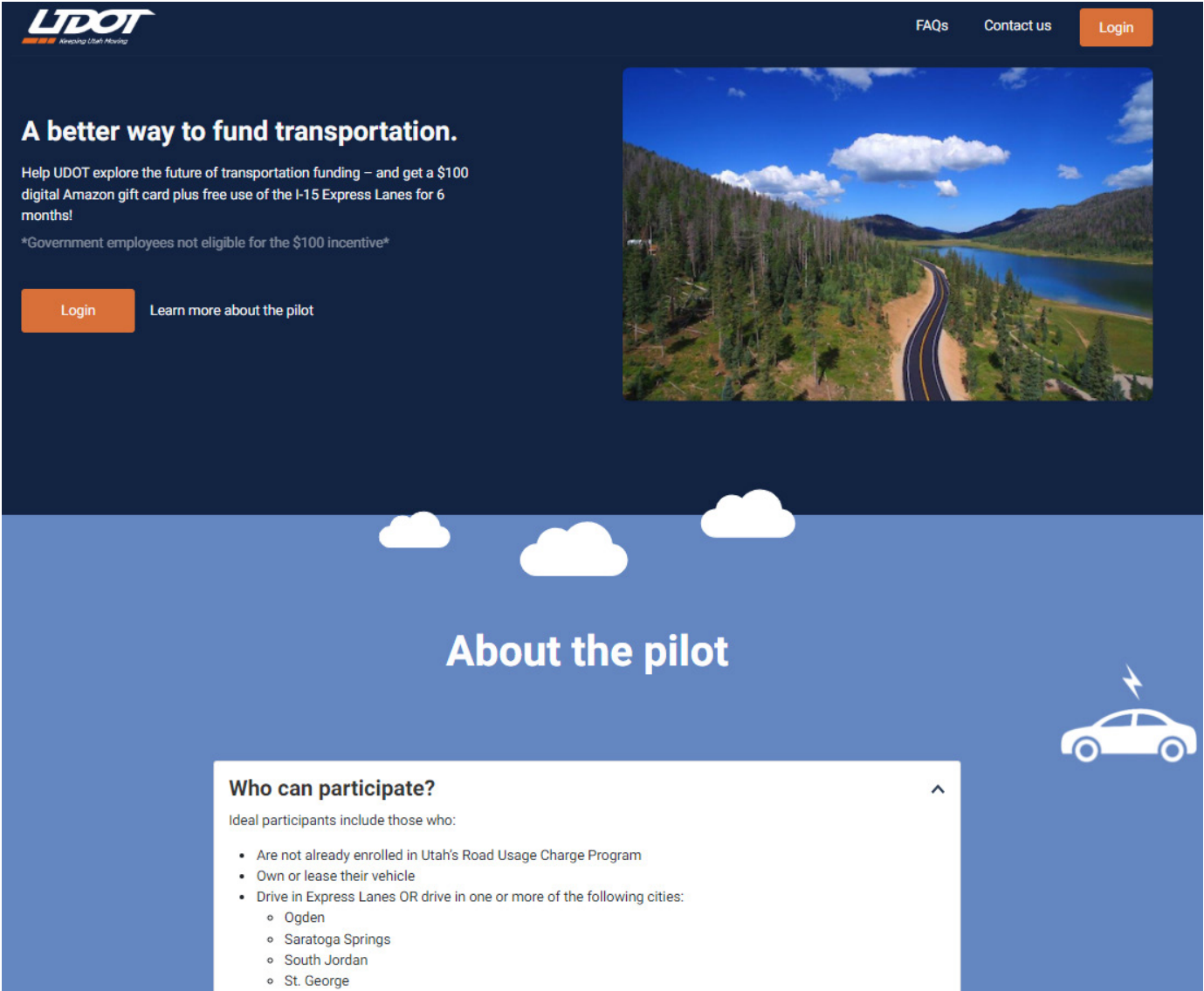


In January 2023, the CAM began their system development activities to meet the defined system design, requirements, business rules, and specifications. UDOT supported the CAM through their pilot system development, working through pilot design and requirements refinement, and met weekly during implementation to review progress and provide feedback and guidance as needed. UDOT reviewed the CAM’s web portal design, participant statement, and all participant communications and provided important feedback.

2.3.1 PILOT WEBSITE

The CAM, in coordination with UDOT, developed a pilot website (<https://udotrucpilot.org/>) to share information about the pilot with potential participants (**Figure 3**). This website included information about what an RUC is, the objectives of the Utah Local RUC and Tolling Integration Pilot, who can participate, and more information about what it means to participate. The website also included important frequently asked questions (FAQs) and a link to express interest in participating in the pilot.

Figure 3. Pilot Website



2.4 PILOT TESTING

Following system development, UDOT coordinated with the CAM to execute testing of the pilot system functionality to verify the system was ready for operational use and met the requirements prior to launch.

The testing consisted of unit testing and end-to-end (E2E) system testing. First, unit testing was conducted by the CAM on the MRDs and account management systems to validate the requirements in the SRS, BRD, and ICD were met. Results were provided to UDOT, who reviewed the unit test results and provided feedback.

Following the unit testing, UDOT developed a test plan for E2E testing that was intended to evaluate the full turnkey capability of the CAM's pilot system. This E2E testing was based on operational scenarios and was aimed to verify that the pilot system was ready for operational use and met the objectives identified by the pilot team. Testers went through the full user experience from account creation to account closeout. The E2E test consisted of the following test case categories that represent different operational areas of the pilot:



Test Case A: Pre-Enrollment, Enrollment, and Account Management



Test Case B: Data Collection (Logbook, Mileage, and Tolling Charges)



Test Case C: Statements and Simulated Wallet



Test Case D: Customer Service



Test Case E: Software and Hardware Design Checks



UDOT carried out the E2E testing with the support of the CAM vendor from mid-June 2023 through late July 2023, using field driving tests and desktop analysis such as reviewing mileage messages, statements, communications, etc. An issues log was maintained throughout testing to document system functionalities that were not yet fully ready for operations. This log included the type of issue, who logged the issue, date it was observed, which test procedure it aligned with, description, priority of the item, current status, resolution date, and confirmation date of resolution. Depending on the results of the test procedures, the test scenario was declared with an overall “pass”/“conditional pass”/“fail” result. “Pass” meant the pilot system was successful under the test scenario and no further action was needed from the CAM. “Conditional pass” or “fail” meant the testers found issues which were tracked in the issue log until they were resolved.

The CAM provided responses or proposed actions for each issue documented and made any appropriate system updates. UDOT tracked the progress on the issues and their resolution over the pilot system updates and retest period from late July 2023 to September 2023.

The CAM resolved the issues relating to all “fail” and most of the “conditional pass” results to UDOT’s satisfaction. For a few “conditional pass” results, the CAM system’s limitation did not allow the associated issue to be resolved, but, in these instances, UDOT deemed the impact on the pilot to be minimal. Upon completion of the E2E testing, UDOT found that the CAM vendor was prepared for launch and recommended the pilot proceed to a “soft launch.”

UDOT conducted a two-week “soft launch” with approximately 10 UDOT and project team staff prior to the official pilot launch. These selected participants completed the full enrollment and MRD installation process and accessed their accounts through the CAM’s web portal to test and correct any unexpected operational performance issues prior to the pilot launch.



The E2E testing covered all of the common and specific testing needs of the pilot concept to achieve the primary goals of the pilot, with the exception of the ability to use an MRD to estimate toll charges. The remaining results from the E2E testing were satisfactory and deemed to be in compliance with the existing SRS and BRD to support the pilot and its concepts. However, there were a few limitations of the system that may require further development. Future updates to the pilot system requirements could address the following types of issues that were encountered and not resolved:



MRD Vehicle Compatibility Check

There were a number of vehicle makes, models, and years that were not compatible with the MRD used in the pilot, and the CAM's system did not support a compatibility check of a vehicle to confirm if the vehicle identification number (VIN) associated with the vehicle was compatible with the MRD. Including an MRD vehicle compatibility check upon vehicle enrollment should be included into the CAM's system. In the pilot, this was accommodated by adding a manual process during enrollment, which is described in Section 3.2.



Online Portal Address Verification

The CAM's online portal does not currently support verification of address and zip code. As a work-around, the CAM is utilizing customer service representatives (CSRs) to verify pilot participants' addresses prior to shipping out the MRDs. Address verification should be automatic to reduce the need for manual intervention and speed up the process for device shipment.



Statement Template

UDOT provided feedback on the statements to increase the user friendliness of statements to match industry standards and best practices. While the CAM considered these, they were unable to incorporate changes for the pilot. For example, the statement did not include the starting and ending wallet balance. Another important requirement to show both toll and RUC transactions in the statement was not met by the CAM vendor. The statements provided total RUC transactions and total toll transactions; however, the detail of both these charges was only available on the participant account portal.

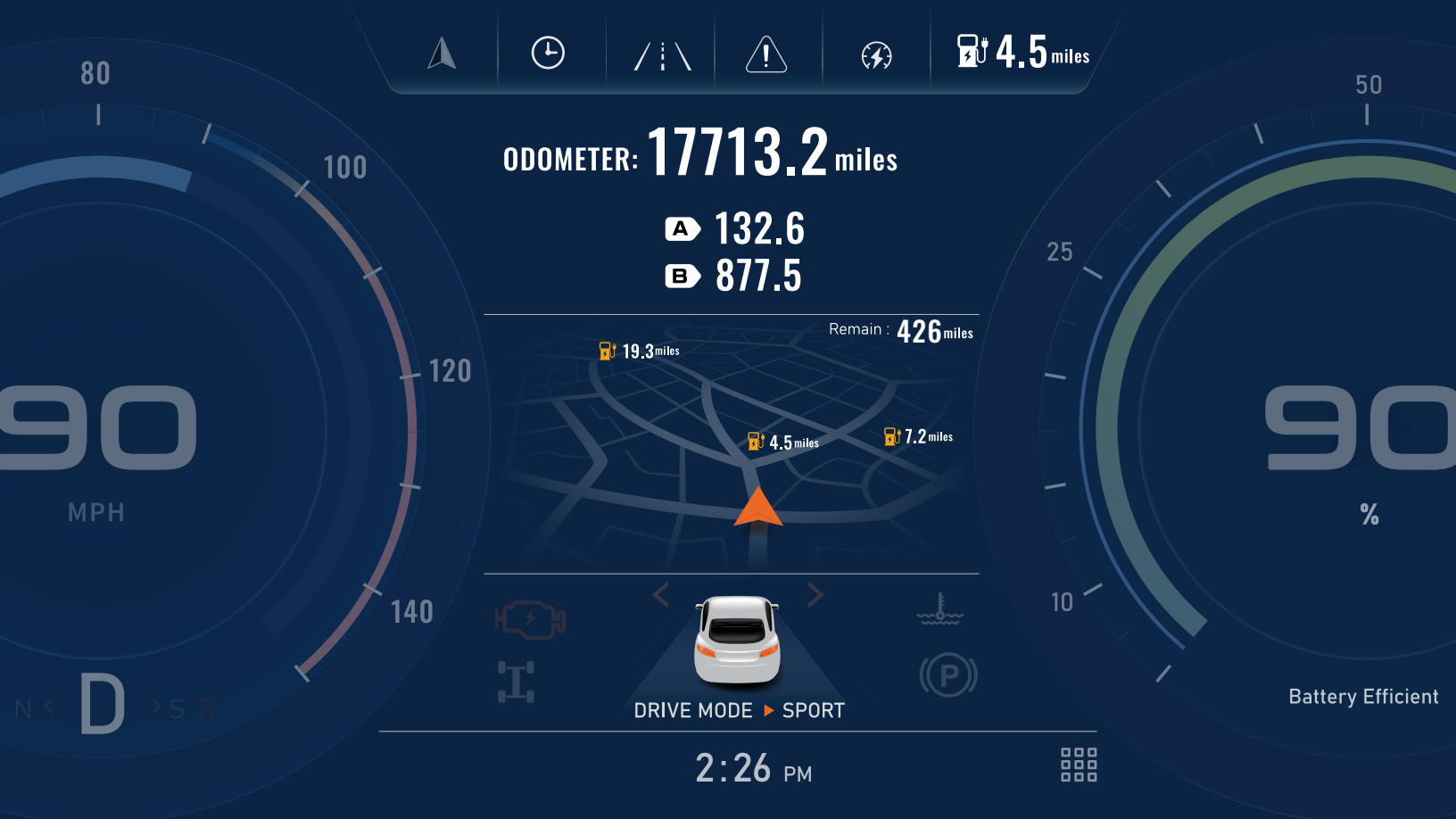


Timely Transaction Posting on Statements

The CAM required at least two consecutive days of trip activity within the same month for the trips to be reflected within the same month's statement. Trips that occur in the same month should be reflected when the statement is generated regardless of the number of trips taken.

SECTION 3.0

RECRUITMENT



3.0 RECRUITMENT

The Utah Local RUC and Tolling Integration Pilot aimed to recruit 100-120 participants to evaluate the integration of RUC with Express Lanes Tolling as well as the feasibility of charging a supplement to the state RUC for the use of local roads.

3.1 RECRUITMENT CRITERIA

To help meet the goals of the pilot, UDOT focused on recruiting Utah citizens who use the Express Lanes and/or are residents of the four cities. UDOT used the following criteria for recruitment:

- Current holders of Express Lanes Accounts with Express Pass, with accounts in good standing
- Citizens who live or drive in one or more of the four participating cities
- City and UDOT employees
 - UDOT invited a selection of UDOT employees and participant City employees to join the pilot to ensure participation from the four cities. In order to test integrated use of tolling, local RUC and state RUC, UDOT offered to open Express Lanes accounts for individuals who did not already have one.
- No participants who were part of the existing Utah Road Usage Charge Program



Incentives

Incentives have proven very effective in pilots to encourage enrollment and participation until pilot completion. UDOT offered two types of incentives to all who participated:

- **Free Tolls:** For the duration of the pilot, and as long as they participated in the pilot, the participants could travel in the Express Lanes free of charge. This was available to all participants.
- **\$100 Digital Gift Card:** This was not available to any Utah government/municipal employees. All other participants were offered a \$100 digital Amazon gift card. To receive the \$100 gift card after the pilot, participants had to complete the following:
 - Enroll in the pilot and plug in the MRD
 - Complete an initial pilot survey
 - Participate and drive in the pilot for 6 months
 - Complete a post-pilot survey



Recruitment Targets

Recruitment was led by the UDOT project team, augmented with the CAM as needed. For the 100-120 participants desired, the breakdown shown in **Table 5** was targeted. These recruiting targets were based on the recruitment criteria above and to fulfill the goals and objectives of the Local RUC and Tolling Integration Pilot. Express Lane account holders help accomplish both the Local Overlay RUC and the RUC and Tolling integration objectives of the pilot. Non-Express Lanes Account holders from the four local cities help ensure the local overlays are all exercised.

Table 5. Minimum Recruitment Targets

	Express Lanes Account Holders	Non-Express Lanes Account Holders	TOTAL
Ogden	15-20	<5	20-25
St. George	<5	15-20	20-25
Saratoga Springs	15-20	<5	20-25
South Jordan	15-20	<5	20-25
Other*	15-20	0	20
TOTAL	60-85	15-35	100-120

* Includes UDOT staff



3.2 USER JOURNEY MAPS

Before starting the recruitment process, UDOT developed user journey maps for both existing Express Lanes account holders and Non-Express Lanes account holders in which UDOT would open accounts on their behalf for the pilot. This helped both UDOT and the CAM understand all the potential touch points with participants before, during, and after the pilot and the responsible parties for these touch points. These user journeys are illustrated in **Figure 4** and **Figure 5**.

Figure 4. User Journey for Existing Express Lanes Account Holders

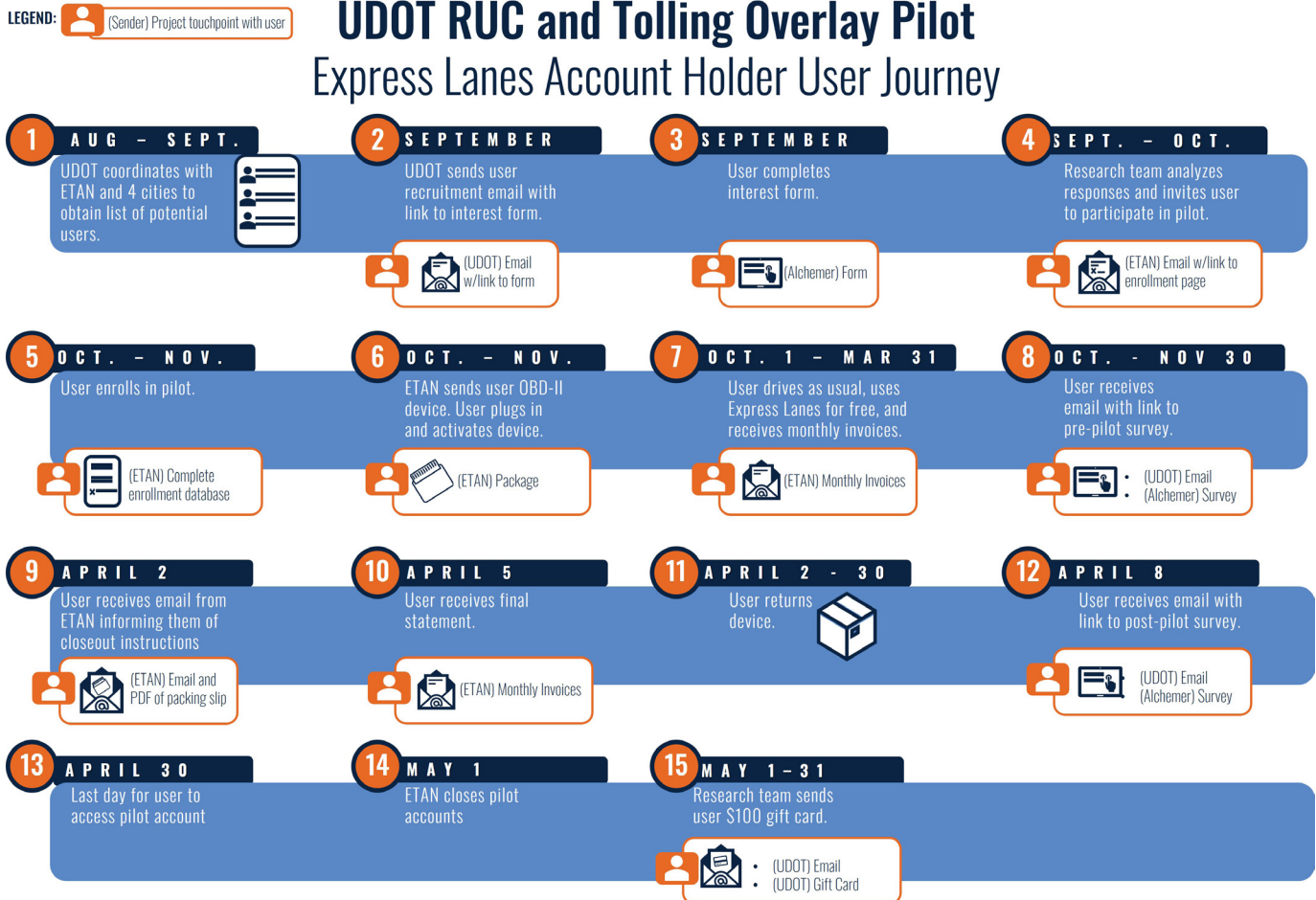
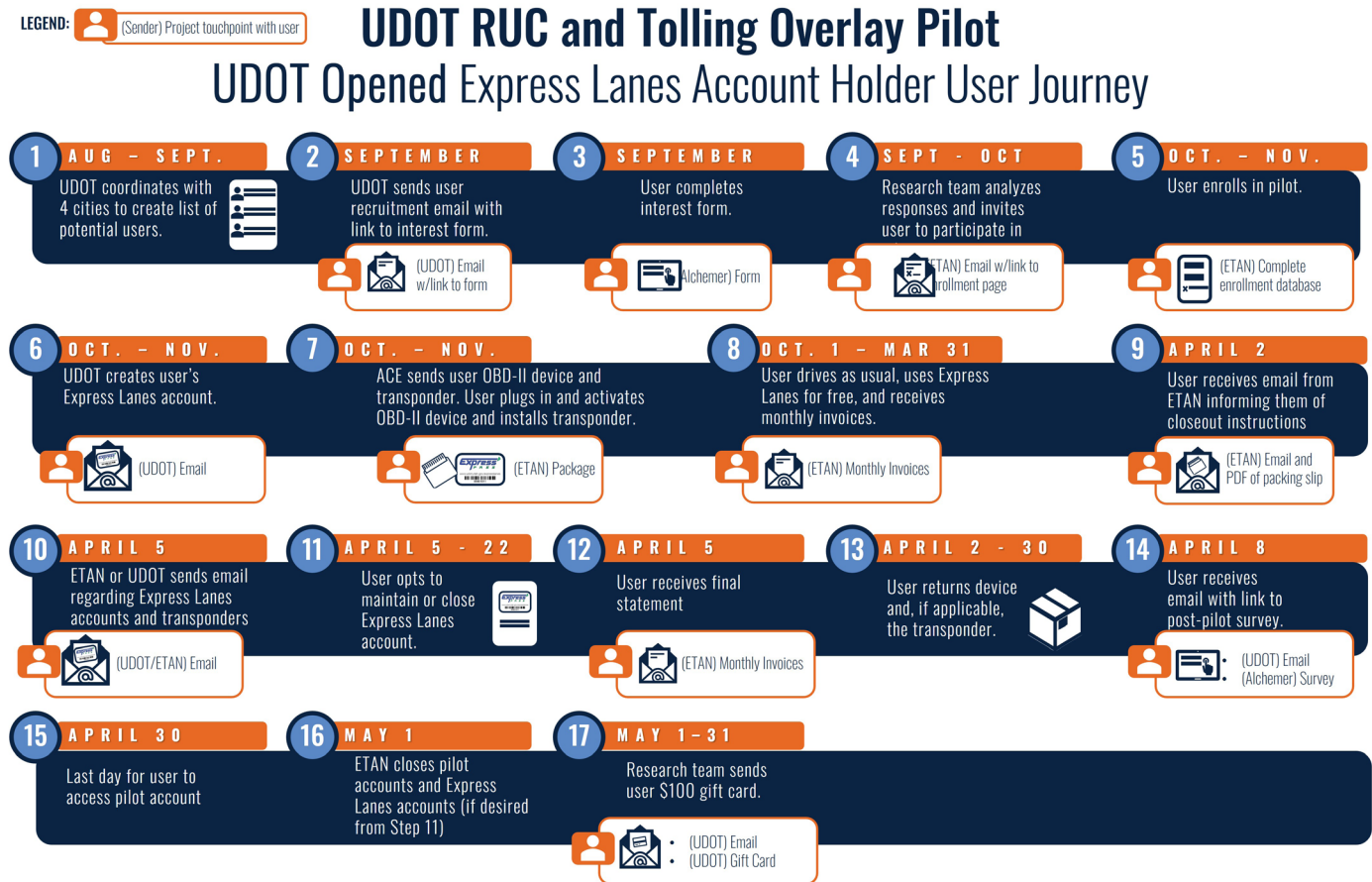


Figure 5. User Journey for “UDOT Opened” Express Lanes Account Holders



3.2.1 RECRUITMENT ACTIVITIES

Recruitment Database

UDOT started by obtaining a list of existing Express Lanes account holders who were both frequent users of the Express Lanes and residents of the partnering local communities. In addition to the list of existing Express Lanes account holders, UDOT coordinated with each of the participating cities on targeted recruits within their respective cities, which included individuals such as city employees, elected officials, or other stakeholders. These efforts culminated into a list of potential recruits.

A recruitment database was set up by UDOT to manage all recruitment activities. This database included all the demographic information about the recruits as well as the recruitment status.



Interest Form

An email was sent to the potential recruits inviting them to complete an online interest form (**Table 6**). In the email invitation, individuals were encouraged to visit the pilot website (<https://udotrucpilot.org/>) to learn more about the pilot, the incentives to participate, and other participation details.

Table 6. Pilot Participant Interest Form

INTEREST FORM QUESTIONS

Are you currently enrolled in Utah's Road Usage Charge Program?		☐ YES ☐ NO
If Yes	Sent message of ineligibility.	
First and Last Name		
Do you currently have an Express Lanes account?		☐ YES ☐ NO
If Yes	Please enter the email address associated with your Express Lanes account.	
If No	Please enter your email address.	
Do you live or work in one of the following cities? Ogden, Saratoga Springs, South Jordan, St. George		☐ YES ☐ NO
If Yes: Which cities do you live or work in?		
☐ Ogden ☐ Saratoga Springs ☐ South Jordan ☐ St. George		
If No: Do you regularly drive in one or more of the following cities?		
☐ Ogden ☐ Saratoga Springs ☐ South Jordan ☐ St. George		
Please provide your vehicle information.		
Make		Model
Year		Note: Vehicles produced before 1996 are ineligible for this pilot.
Are you a state, county, or local government employee?		☐ YES ☐ NO
If Yes	Sent message about ineligibility to receive the \$100 gift card, but can still travel for free in the Express Lanes during the pilot.	

Confirmation Page



Enrollment Invitation

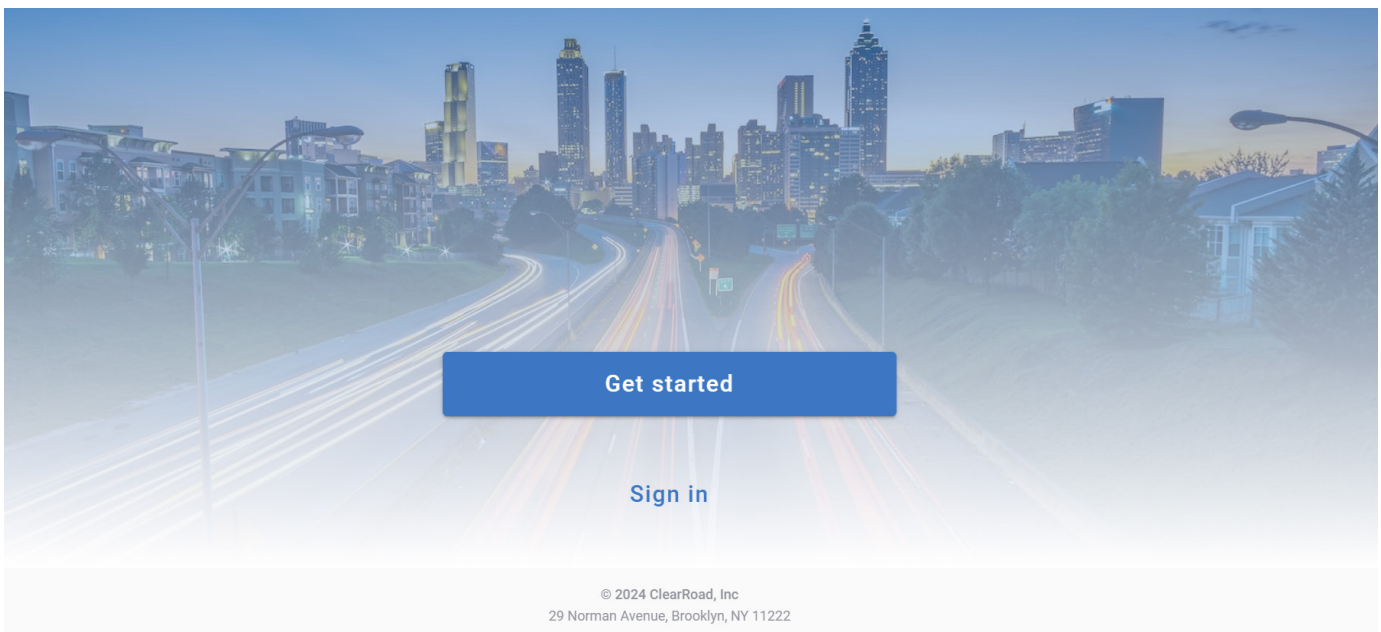
The information provided in the interest form was used to select the best candidates who met the recruitment criteria to help accomplish the objectives of the pilot. An important criterion was the participating vehicle's compatibility with the MRD. The pilot testing, discussed in Section 2.4, revealed that the MRDs used in the pilot were not compatible with a number of vehicle makes, models, and years. As a result, the CAM provided UDOT with a list of vehicle makes/modes/years that were compatible, and UDOT set up a compatibility check in the recruitment database. The vehicle information provided in the interest form was used to verify compatibility with the MRD. If a vehicle was deemed incompatible with the MRD, the participant was not invited to join the pilot.

The results from this process are provided in **Table 7**. A total of 1,245 interest-form emails were sent out, 198 participants completed the interest form (16% response rate), 171 vehicles were found to be compatible (86%) with the MRD devices, resulting in 170 participants being invited to enroll in the pilot.

The pilot enrollment emails included the required information for enrollment (e.g., VIN, vehicle make/model/year, etc.) and an enrollment link to the pilot website developed and hosted by the CAM where participants could enroll and set up an account.

Table 7. Pilot Participant Interest Form Results

# of Interest Form Invitation Emails Sent	# Completed Interest Forms	Interest Form Response Rate	# Vehicles Compatible with pilot MRD	% Vehicle Compatibility	# Invited to Participate in Pilot
1245	198	16%	171	86%	170



Pilot Enrollment/Account Setup Website

Communication during Enrollment

During enrollment, participants had to sign a participant agreement. This agreement outlined the expectations for participating in the pilot and provided information about data collection and use, data retention, and requirements to receive the incentives. In order to participate in the pilot, participants had to agree to plug in the GPS-enabled device to their vehicle to record mileage and location information for local RUC and tolling charges. Participants were also informed that during the pilot, they could travel the Express Lanes free of charge and that they should keep their transponder in the “toll” setting at all times (irrespective of the number of people in the vehicle) to allow for data to be collected for the pilot.

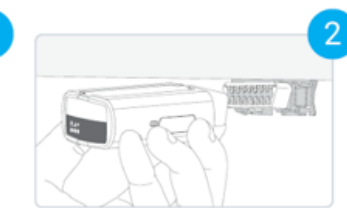
UDOT and City employees who did not have an Express Lanes account and agreed to sign-up for the pilot had to complete one additional step. UDOT opened Express Lane accounts for them using a UDOT credit card. As part of this process, the Express Lane System also sent them a transponder with installation instructions. These accounts would be closed at the end of the pilot.

After successful enrollment, participants were mailed the MRD with instructions on how to install it in their vehicle (**Figure 6**).

Figure 6. MRD Installation Instructions

Four Step Installation

If you have determined that your vehicle is prepared for installation. Please follow the following steps:

1	2	3	4
 Locate the vehicle's engine diagnostic port typically found in the driver's area at or below knee level. * NOTE: Heavy-Duty trucks often use a different Diagnostic Link Connector (DLC).	 Align the receiver end of the device with the engine diagnostic port and push in place. Ensure the device is well connected to the diagnostic port. Once connected, the device emits six quick beeps.	 Once the device is connected and receives power, the LEDs on the front of the device start blinking then turn solid once completing the actions below. Red LED — Device configuration Green LED — Cellular network connectivity Blue LED — GPS network connectivity * NOTE: The device should be in good cellular coverage during installation process.	 The device emits two quick beeps every 60 seconds during set-up. Initial startup may take several minutes to complete. Once all three LEDs turn solid, and you hear 10 quick beeps, secure the device using the provided cable tie. * NOTE: The device starts updating when the green and blue LEDs turn solid.

3.3 RECRUITMENT RESULTS

UDOT and the CAM maintained the recruitment database, which included those selected and invited to participate, those who completed enrollment, and those who were active or had plugged in their MRD and were reporting mileage (**Table 8**).

Table 9 presents the actual recruitment results against the targets that were outlined in Table 5. The total recruits only include the 112 who activated the MRD and reported mileage data; it does not include the 7 participants who didn't complete their device activation.

Table 8. Pilot Participant Recruitment Results

# Invited to Participate in Pilot	# Invited with Express Lanes Account	# Invited with NO Express Lanes Account	# who Enrolled	# who Activated MRD	Enrollment/ Activation Response Rate
170	152	18	119	112	66%

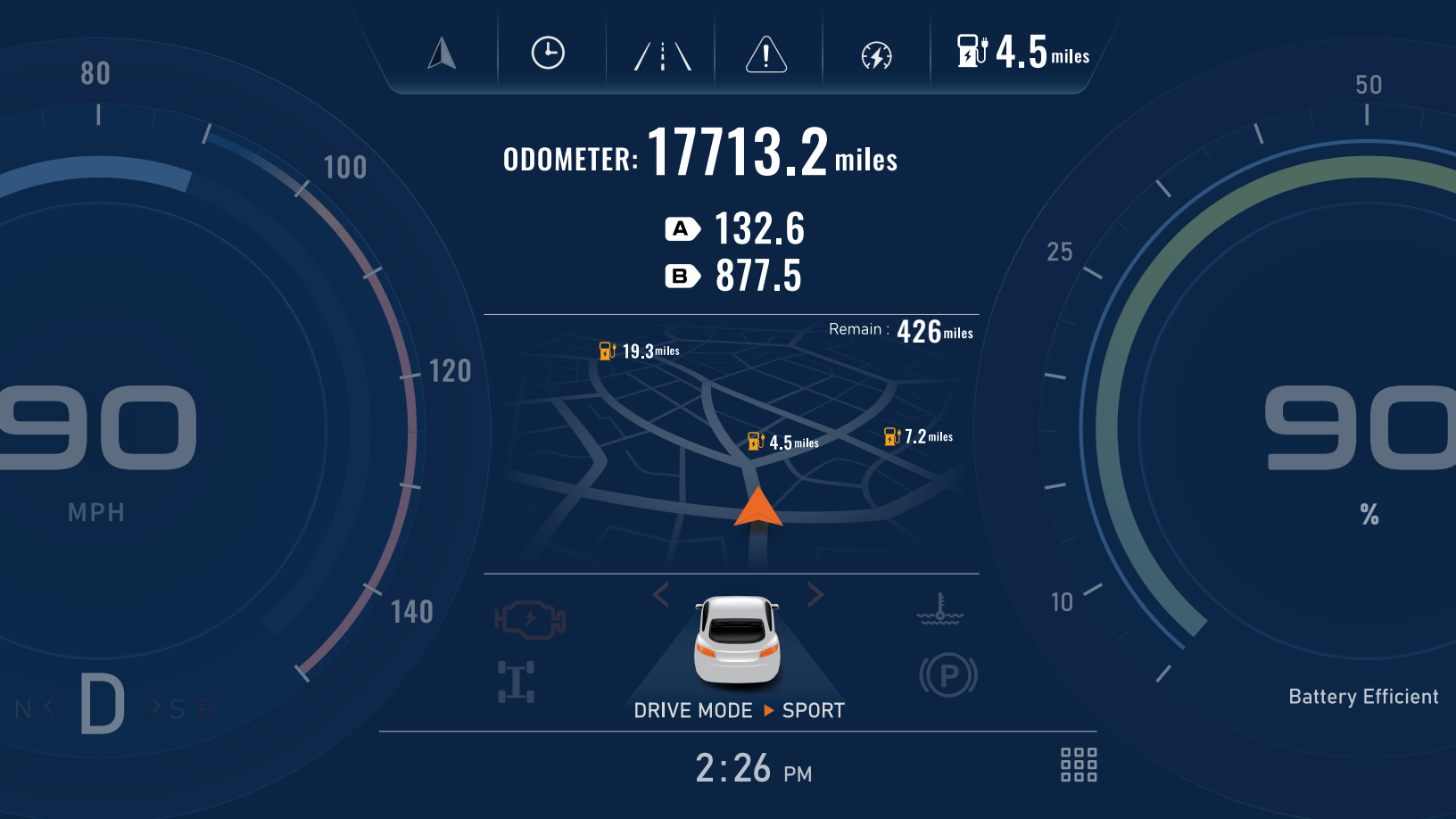
Table 9. Recruitment Targets vs. Actuals

	Express Lanes Account Holders		Non-Express Lanes Account Holders		TOTAL	
	Target	Actual	Target	Actual	Target	Actual
Ogden	15-20	36	<5	2	20-25	35
St. George	<5	0	15-20	4	20-25	4
Saratoga Springs	15-20	18	<5	4	20-25	22
South Jordan	15-20	25	<5	3	20-25	26
Other*	15-20	18	0	2	20	20
TOTAL	60-85	97	15-35	15	100-120	112

* Includes UDOT staff

SECTION 4.0

PILOT OPERATIONS



4.0 PILOT OPERATIONS

With the help of the federal STSFA grant, the Utah Local RUC and Tolling Integration Pilot launched on October 2, 2023, and ran for six months concluding on March 31, 2024. In support of live pilot operations, UDOT met regularly with the CAM to ensure the pilot progressed well and monitored and spot-checked operations.

4.1 ENROLLMENT AND ACTIVATIONS

Enrollment began on October 2, 2023, and by the end of December, there were 119 participants enrolled in the pilot. Of the 119 participants, 112 activated their MRD (plugged in their device and were reporting mileage). From these 112 who activated, 5 participants were removed from the pilot shortly after joining due to reasons outlined in **Table 10**. This resulted in a total of 107 participants completing the six-month pilot. It should be noted that four participants expressed concerns that the MRD drained their battery. These inquiries were escalated to the CAM and then the MRD manufacturer, but there was no confirmation the MRD caused the battery issues.

Table 10. Participant Reasons for Not Completing the Pilot

Count	Reason
4	Removed from the pilot due to the participant reporting battery issues when MRD was plugged in. The MRD manufacturer has not confirmed these issues.
1	Removed from pilot after participant reported that they have sold the vehicle and did not want to register a replacement vehicle.



Figure 7 shows the total number of participants who enrolled in the pilot by month, activated their MRD, and completed the pilot through March 2024. There were no additional enrollments or activations after December 2023.

Figure 8 shows the total number of participants who indicated they live or work in Ogden, Saratoga Springs, South Jordan, St. George, with the “other” category primarily including I-15 Express Lanes users who don’t reside or work within the four cities.

Figure 7. Enrollments and Activations by Month

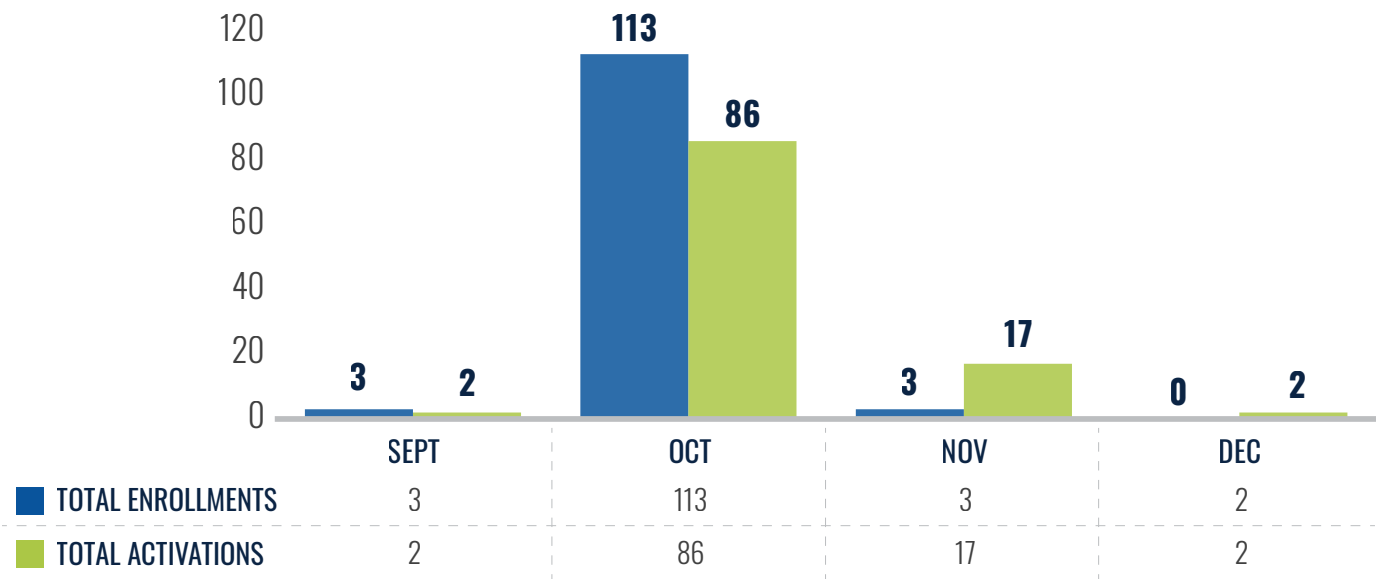
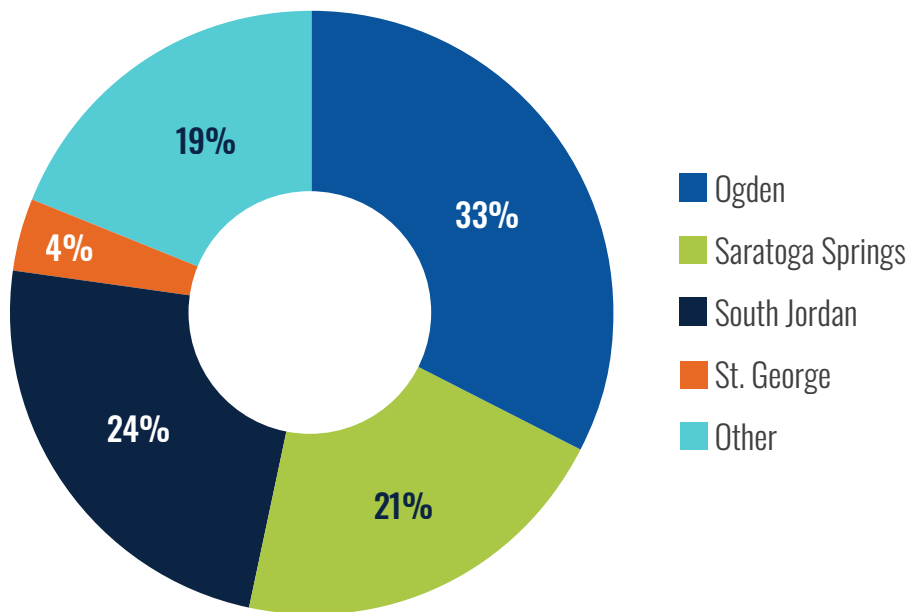


Figure 8. Percentage of Participants Activated by Region



Upon enrollment completion and activation of the MRD, all participants had the opportunity to experience both the tolling and local overlay aspects of the pilot. Which aspects they experienced depended on where they drove; experiencing the tolling required them to use the I-15 Express Lanes; experiencing the RUC Local Overlay required them to drive through one or more of the four participating cities. An initial survey and post-pilot survey was distributed to all participants to solicit feedback and help UDOT evaluate the user experience for a combined state RUC/local RUC/tolling program. These surveys and the results are discussed in more detail in Section 5.

4.2 INTEGRATION WITH EXPRESS LANES

In order to integrate tolling and RUC charges, the following processing was needed:

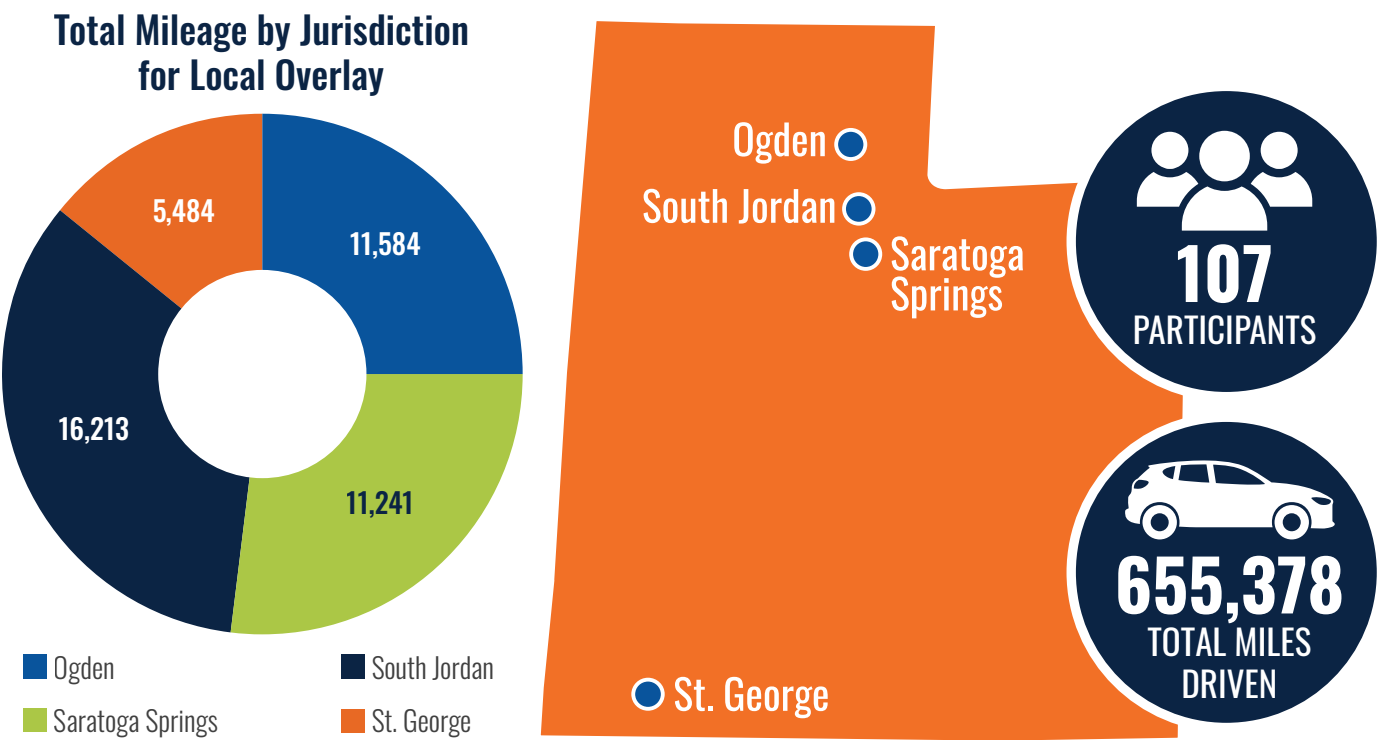
- The tolls were posted to the Express Lanes customer accounts.
- The transponders belonging to pilot participant accounts were white-listed by the Express Lanes vendor in their system.
- The Express Lanes system posted a credit transaction equivalent of the toll charges for every toll transaction posted in the Express Lanes accounts of the pilot participants every night. These toll transactions were sent via an interface to the RUC pilot system.



4.3 RUC MILEAGE, CHARGES AND TOLL ACTIVITY

The CAM provided monthly reports to UDOT, which included customer support statistics, local and state RUC trip statistics, Express Lane toll usage statistics, and other raw data collected. Over the six-month pilot, the 107 active participants drove a total of 655,378 miles with 44,522 miles driven within the four participating cities (Figure 9).

Figure 9. Utah Local RUC and Tolling Integration Pilot Statistics



All RUC mileage driven by pilot participants was charged at the state RUC rate at the time the pilot launched, which was \$0.01/mile. In addition, all miles driven within the four participating cities involved in the pilot were charged the surcharge amount shown in Table 3, excluding any miles driven on state routes within these city limits. **Table 11** reflects the breakout of mileage activity and RUC charges from October 2023 through March 2024.

Figure 10 shows the breakout of general total miles driven each month from October 2023 through March 2024 as well as the total RUC charges.

Table 11. Breakout of Mileage Activity and Charges by Jurisdiction

Month	Total Miles		Ogden		Saratoga Springs		South Jordan		St. George	
	Miles	RUC Charge \$0.010/ Mile	Miles	RUC Charge \$0.006/ Mile	Miles	RUC Charge \$0.007/ Mile	Miles	RUC Charge \$0.007/ Mile	Miles	RUC Charge \$0.007/ Mile
Oct-23	62,444	\$624.44	1,170	\$7.02	1,021	\$7.14	1,415	\$7.07	190	\$0.76
Nov-23	114,882	\$1,148.82	2,101	\$12.60	1,962	\$13.73	2,908	\$14.54	1,012	\$4.05
Dec-23	116,724	\$1,167.24	1,842	\$11.11	2,152	\$15.07	2,997	\$14.99	1,669	\$6.67
Jan-24	119,452	\$1,194.52	2,102	\$12.61	2,005	\$14.03	3,164	\$15.82	1,135	\$4.54
Feb-24	120,784	\$1,207.84	2,185	\$13.11	1,950	\$13.65	2,911	\$14.56	739	\$2.96
Mar-24	121,093	\$1,210.93	2,174	\$13.04	2,152	\$15.06	2,817	\$14.09	740	\$2.96
Total	655,378	\$6,553.79	11,584	\$69.49	11,241	\$78.68	16,213	\$81.07	5,484	\$21.94

Figure 10. Total Miles Driven and RUC Charges

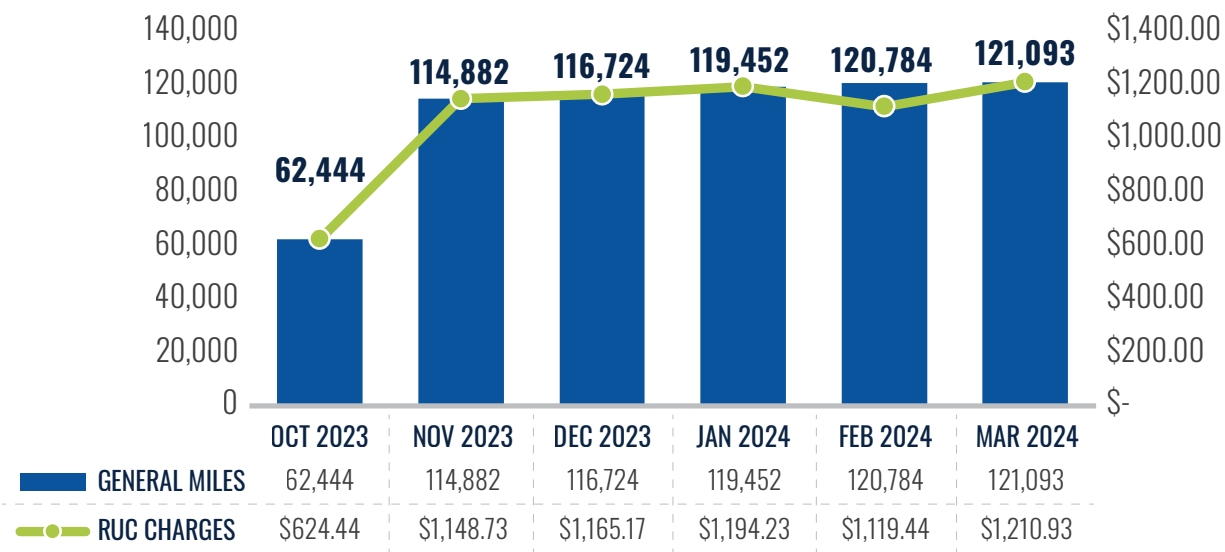


Figure 11 provides the breakout of local RUC charges for miles driven within the four participating cities (Ogden, Saratoga Springs, South Jordan, and St. George) from October 2023 through March 2024.

Figure 12 shows the number of Express Lane toll trips and the associated charges accrued by pilot participants from October 2023 through March 2024. Over the six months, participants completed 7,542 toll trips for a total of over \$9,000 in toll charges.

Figure 11. Local RUC Charges

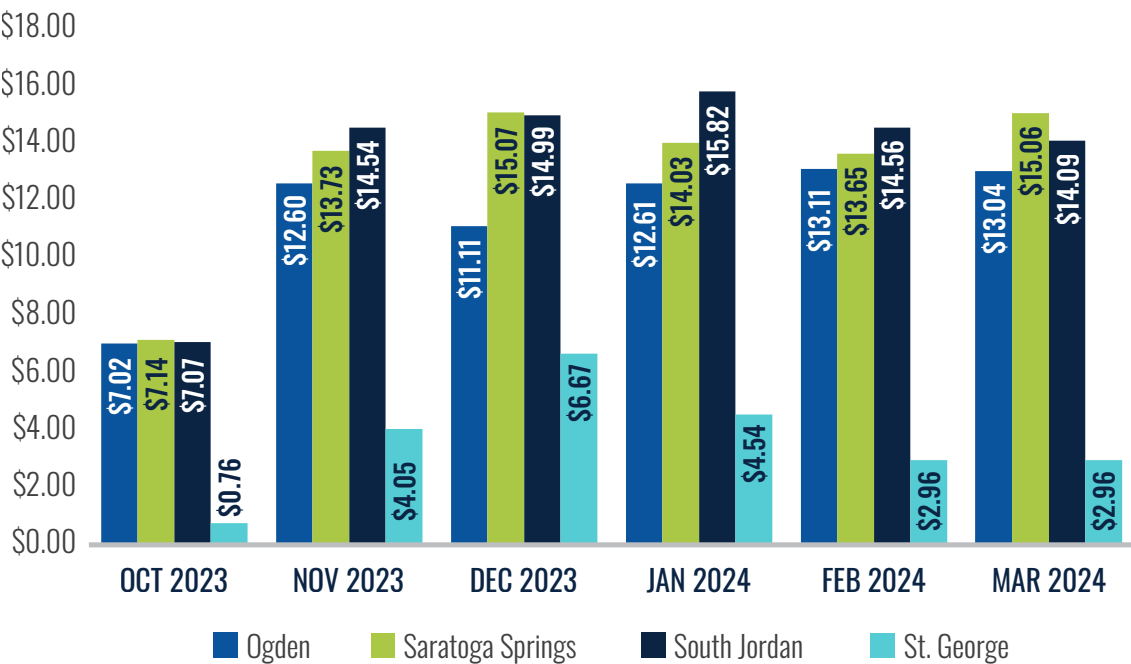
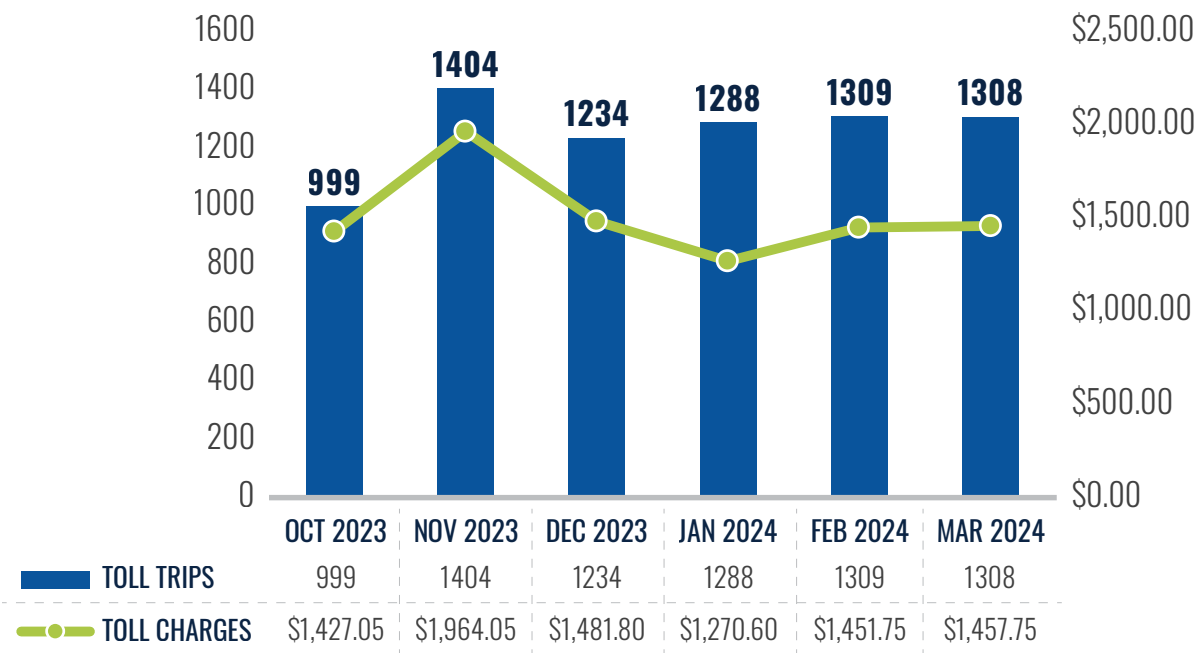


Figure 12. Toll Trips and Charges



The total revenues “collected” (all charges were simulated, no real money was collected) for tolls, state RUC, and local RUC over the six-month pilot are summarized in **Table 12**.

4.4 CUSTOMER SUPPORT ACTIVITY

The CAM provided live customer support via email and telephone for the pilot participants throughout the duration of the pilot Monday through Friday from 7:00 a.m. to 5:30 p.m. MST. The CAM maintained a log of all customer support inquiries received during the pilot, which included both inbound and outbound calls. Throughout the pilot period, a total of 46 calls were handled via telephone and 25 emails (**Table 13**).

Table 12. Total Revenues by Method

Revenue Method	Revenue
Tolls	\$9,053.00
State RUC	\$6,551.92
Local RUC	\$251.18
Total Revenue	\$15,856.10

Table 13. Customer Support Calls by Month

Month	Number of Calls	Number of Emails	Total Inquiries
October 2023	12	11	23
November 2023	12	5	17
December 2023	11	1	12
January 2024	4	4	8
February 2024	5	1	6
March 2024	2	0	2
April 2024	0	3	3
Total	46	25	71



Figure 13 shows the type of customer inquiries received over the six-month pilot with the majority related to the plug-in devices, either reminders to plug them in or issues/questions related to device installation or returns.

The CAM also captures errors and events associated with the initial connection of the MRD and any subsequent unplug events. **Table 14** below summarizes the unplug events over the six-month pilot. As of March 31, 2024, there were a total of 546 unplug events across 108 unique MRDs. Note that there are a few unique MRDs with unplug events occurring in more than one month. Over the course of the pilot, and during testing, there were a number of instances where the MRDs became loose in the vehicle’s second-generation onboard diagnostics (OBD-II) port, and the driver would not realize that it wasn’t reporting mileage. These instances required the CSRs or UDOT to reach out to participants to check/reinstall their MRD so it would report data again.

Figure 13. Customer Support Inquiries by Type

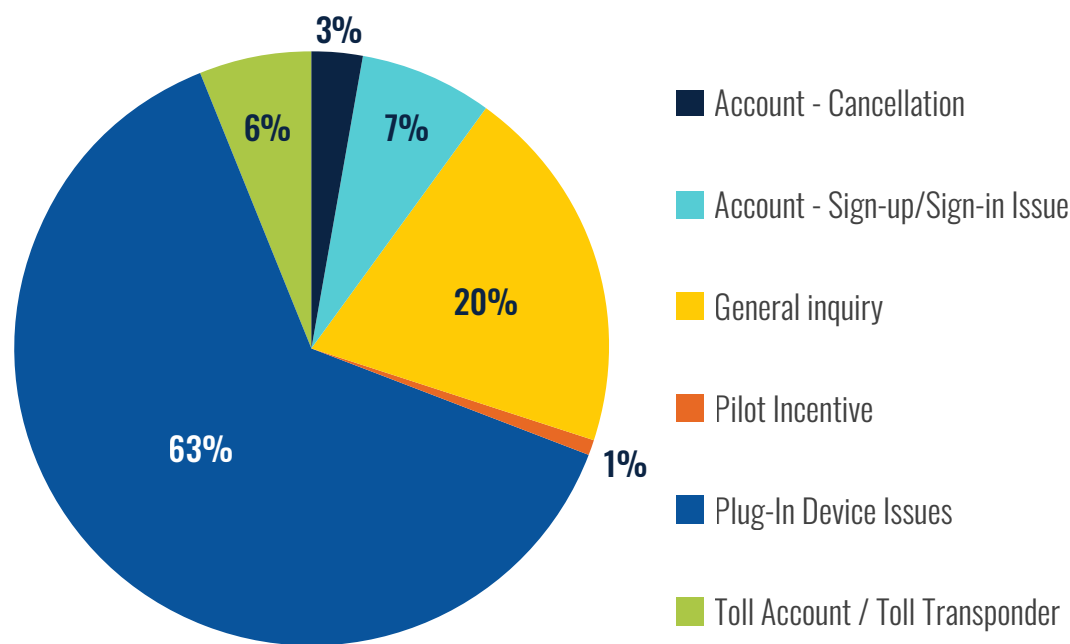


Table 14. Summary of Unplug Events by Month

Month	# of Unplug Events	# of MRDs associated with Unplug Events
October 2023	35	25
November 2023	97	28
December 2023	116	31
January 2024	95	34
February 2024	76	27
March 2024	127	31

4.5 COMBINED WALLET ANALYSIS

Section 2.2.5 discussed the three different sets of values that were tested for the single, combined, *simulated* electronic wallet, from which all charges were deducted. Upon completion of the pilot, UDOT used the pilot data to determine how frequently the simulated wallets needed to be replenished for each of the three options. This analysis can help determine parameters like optimal initial balance, minimum threshold, and replenishment amount.

As shown in **Figure 14**, Set 3 required approximately half the number of replenishments as Set 1 (\$25) each month. In addition, for Sets 2 and 3, the majority of accounts only had one wallet replenishment per month while Set 1 required multiple replenishments per month (**Figure 15**).

Larger initial balances and replenishment amounts lessen the replenishment frequency, which reduces the credit card fees for the Agency as credit card fees include per-transaction fees in addition to a percentage of the transaction amount. However, a higher initial balance and replenishment amount for all participants may not be fair to participants with less usage, and it may even be financially burdensome and discourage program participation.

The two competing considerations may be overcome by allowing the participants to select their initial balance and replenishment amounts among a set of low, medium, and high amounts. The system can guide the participants to estimate their usage initially to select the initial balances and replenishment amounts. The system should evaluate these values against the actual usage over a period of time (e.g., 3 months) and adjust the replenishment amounts as needed.

Figure 14. Wallet Replenishments by Month

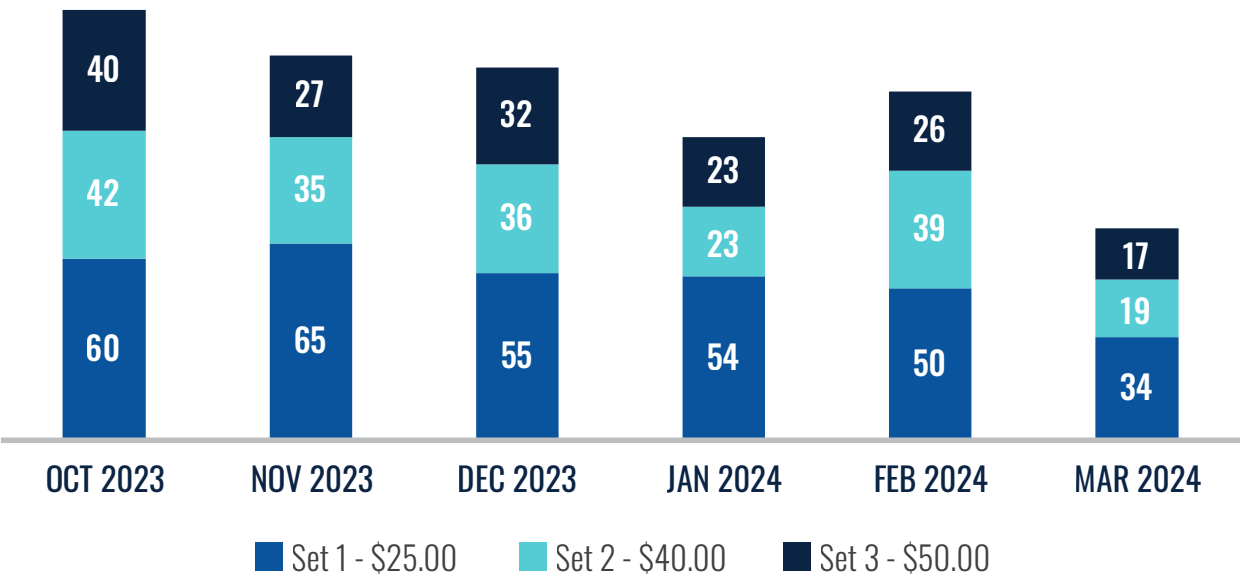
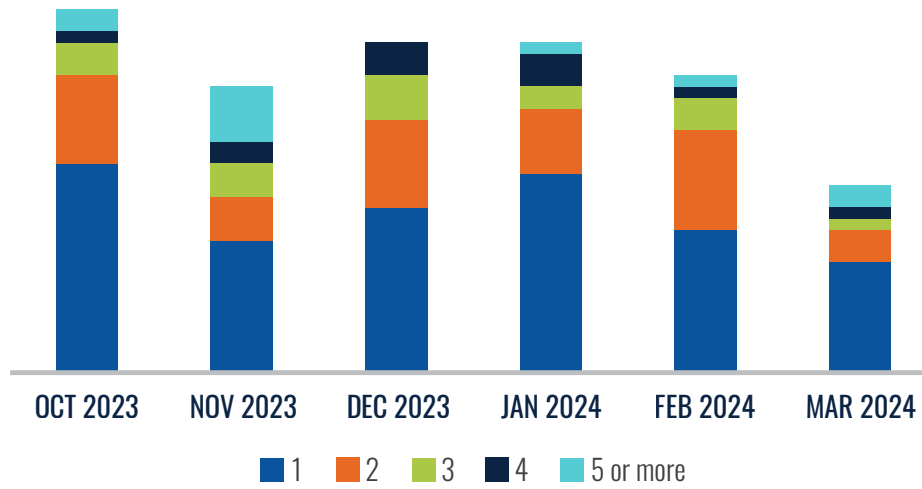
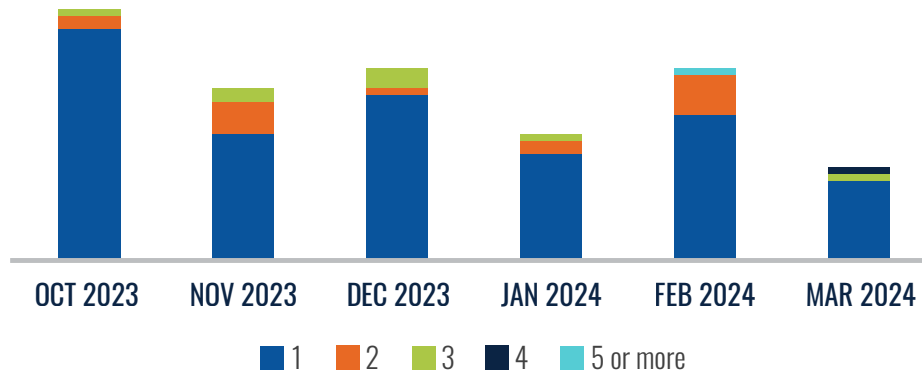


Figure 15. Frequency of Replenishments by Month by Set

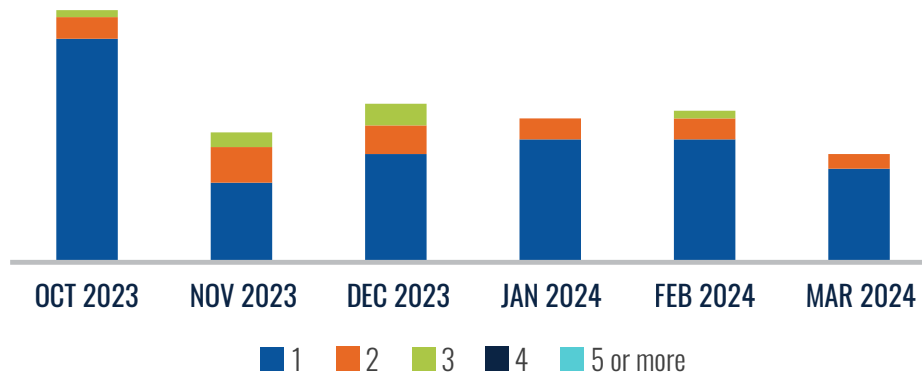
Set 1 (\$25.00) - Frequency of Replenishments



Set 2 (\$40.00) - Frequency of Replenishments



Set 3 (\$50.00) - Frequency of Replenishments



4.6 PROOF-OF-CONCEPT TEST

Since the plug-in devices used in the pilot were unable to detect toll usage in the Express Lanes, the UDOT project team partnered with Verra Mobility to conduct a proof-of-concept test to evaluate if transaction information from telematics (utilizing GNSS technology) can be used as a proxy to transponder readings in I-15 Express Lanes in Utah.

The high-level objectives of this proof-of-concept test included:

- Demonstrating the ability to properly identify a toll transaction leveraging connected vehicle technology to determine the appropriate toll charge
- Matching a transponder transaction captured with a corresponding connected vehicle toll transaction
- Assessing the completeness of information received from a connected vehicle toll transaction to process a toll payment
- Providing comprehensive data to aid in trip building by capturing data from all toll points

In addition, Verra Mobility also tested the ability to automatically detect and record vehicle occupancy and validate eligibility for high occupancy vehicle (HOV) lane usage. This was not a pilot objective, but this information was collected and validated as the system provided the information. In a future deployment, this information could be used to determine vehicle occupancy and application of appropriate toll rates.

The proof-of-concept test was conducted over a period of two weeks utilizing three vehicles using the original equipment manufacturer's (OEM's) onboard telematics and infotainment systems. Vehicle occupancy was established through passenger detection by the OEM embedded systems using sensors in the seats.



Table 15 summarizes the scenarios tested and the results observed during the proof-of-concept test.

The objectives set forth in this pilot study were successfully completed. It was demonstrated that GNSS data obtained from a connected vehicle can be used to capture toll transactions on Utah's I-15 Express Lanes. GNSS tolling offers several advantages over traditional hard infrastructure tolling systems. For instance, it provides flexibility and efficiency without the need for additional toll booths or physical infrastructure on the roads, reducing costs and minimizing traffic disruptions. These solutions can also be easily adjusted, allowing for dynamic pricing models to effectively manage road usage.

However, there are challenges to implementing GNSS tolling. Privacy is a major concern as the system inherently tracks vehicles' movements. Ensuring that the system is secure, reliable, and accurate is important, as is finding a fair and effective way to handle noncompliant users.

Additional details on this proof-of-concept test are provided in the full report included in **Appendix A**.

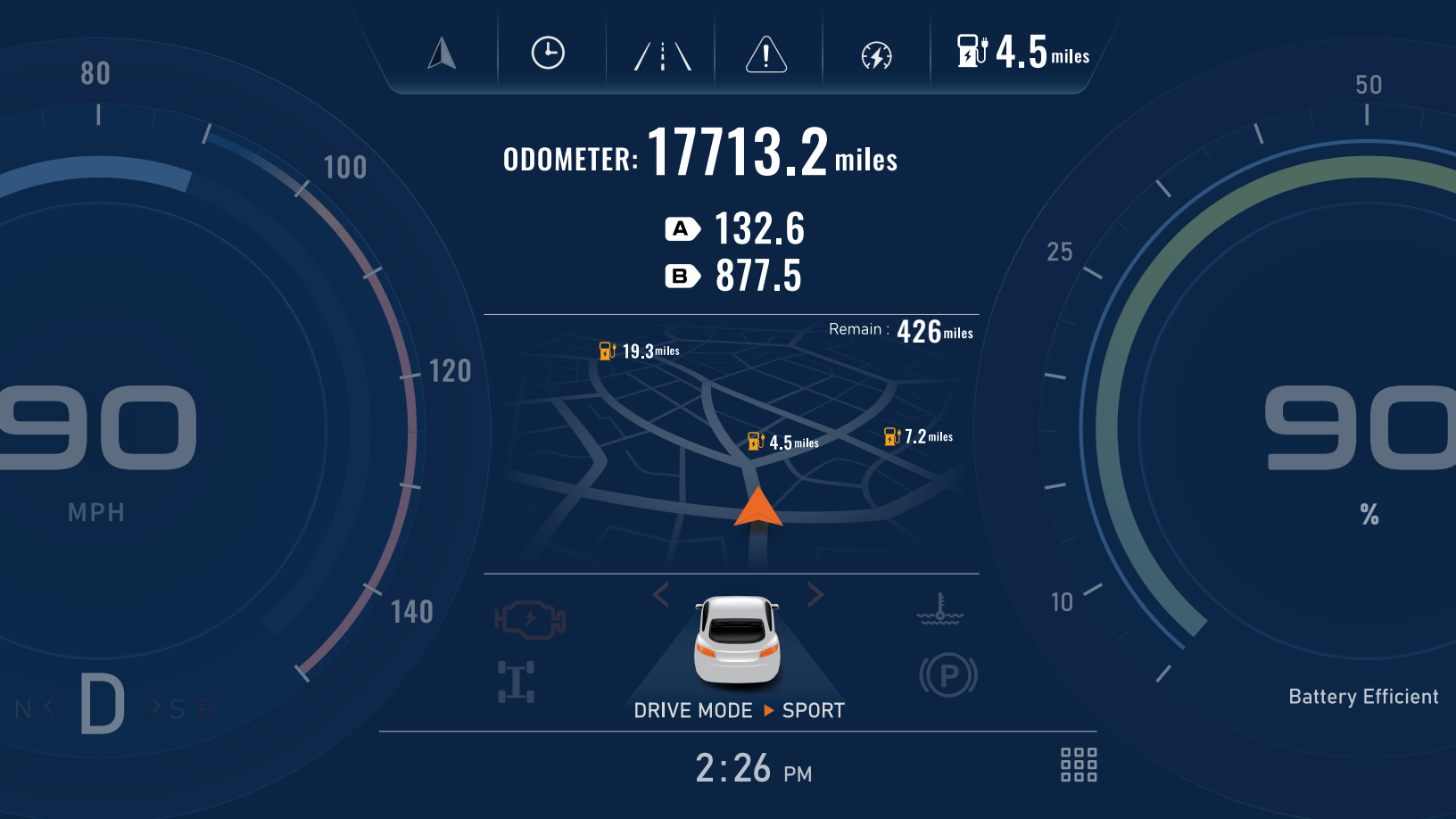
Table 15. Test Cases and Results

Month	Description	Test Method	Expected Outcome	GNSS Toll Accuracy
Express Lane Tolling	Driving on the HOV Toll lane with no passengers	Drive along the full stretch of the HOV Express Lane NB/SB	The GNSS captures match the toll transactions read by the transponder	Vehicle identification - 100% Relative location of toll transaction – 94%*
Toll lane proximity testing	Driving on the general purpose lane adjacent to the HOV Toll lane	Drive very closely on the lane to the right of the HOV Toll lane, along the full stretch of the Express Lane NB/SB	There should not be any toll transaction captured through GNSS data	97.5%
Occupancy testing	Driving on the HOV Toll lane with a passenger (2+ configuration)	Drive along the HOV lane with 2 people in the vehicle.	The vehicle data indicates 2 occupants in the vehicle and notifies the system that the vehicle qualifies for HOV rates.	100%
Toll Evasion	Driving in a way such that a transponder read is avoided at the gantry	Driving on the HOV Toll lane until reaching a toll gantry and then jumping lanes to avoid a toll capture	The GNSS data captures the path taken by the vehicle on the HOV Lane and identifies lane usage and calculates toll charge accordingly, even if the vehicle evades toll gantry.	100%

**Result of unexpected OEM Software release during the pilot, caused accuracy to be lower.*

SECTION 5.0

PARTICIPANT SURVEYS



5.0 PARTICIPANT SURVEYS

To gather feedback about the pilot experience, pilot participants were invited to complete two online surveys:

- **Initial Survey:** This survey was sent out to participants after they completed their enrollment in the pilot, received their MRD, and activated the MRD (successfully reporting mileage).
- **Post-Pilot Survey:** This survey was sent out to all participants on the same date, April 8, 2024, one week after the Utah Local RUC and Tolling Integration Pilot concluded.

Participant surveys covered several topics. Regarding the RUC Local Overlay, the surveys assessed participants' understanding of the RUC Local Overlay concept, their comprehension of the pricing (state and local charges) and how it could be better communicated, their understanding of the web portal display of the RUC Local Overlay, whether participants would change their travel behavior with an RUC Local Overlay, the clarity of monthly statements in displaying RUC Local Overlay charges, and the significance of privacy concerns with the local RUC. For the Integration of RUC and Tolling, the surveys explored how well the tolling and RUC charges in the CAM's web portal were understood, the effectiveness of the combined electronic simulated wallet, the clarity of monthly combined statements, and the significance of privacy concerns with tolling integration.

Completion of both the initial and post-pilot survey was required to receive the \$100 incentive. A copy of both the surveys is provided in **Appendix B**.



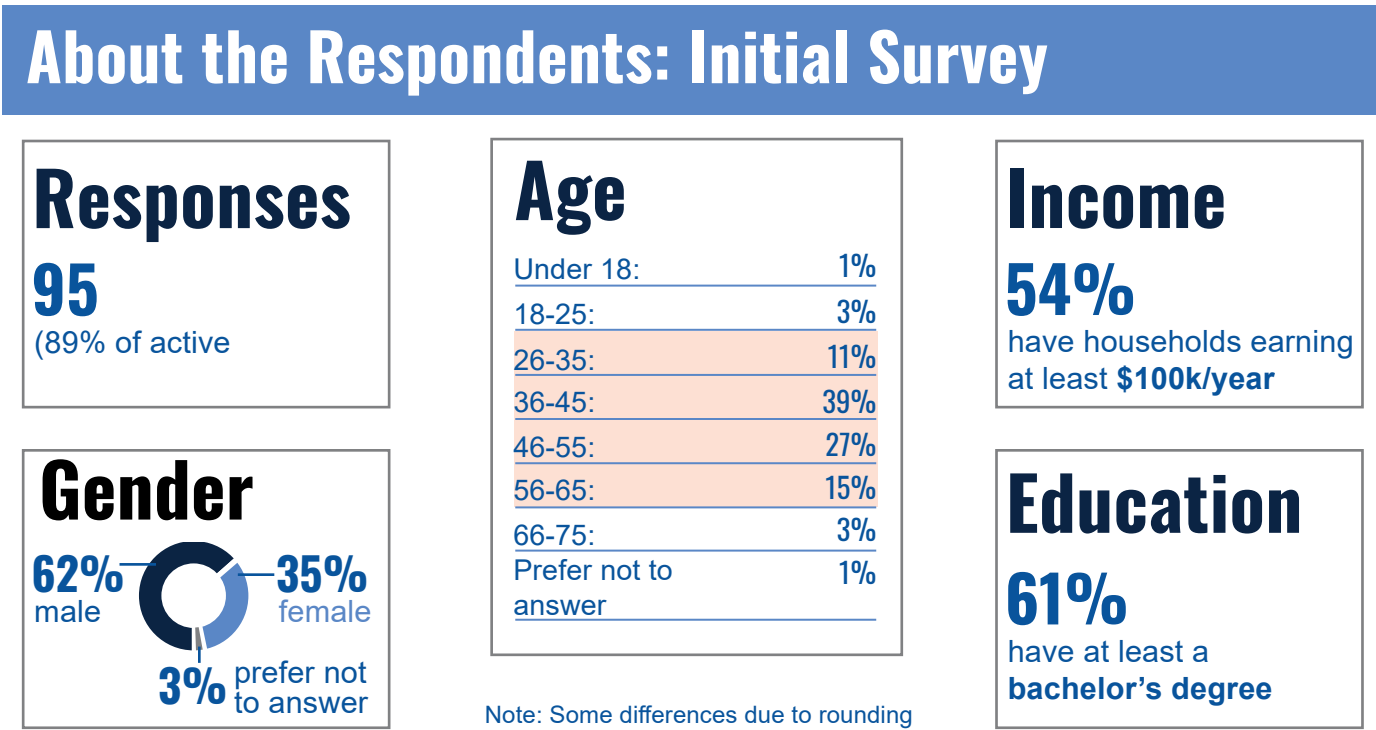
5.1 INITIAL SURVEY

The initial survey focused on the participants experience with the enrollment process and the MRD and toll transponder (if applicable) installation process, as well as their familiarity/ attitude about the RUC concept and their level of comfort providing location information to support the local RUC and tolling.

The initial survey received 95 responses, representing about 89% of active participants. More information about the initial survey respondents is provided in **Figure 16**.

Regarding opinions on RUC, 65% of respondents felt that the overall RUC concept is somewhat or very fair. Additionally, 90% of respondents reported that their account and device setup was somewhat or very easy. Those who found the setup somewhat or very easy were over two times as likely to perceive RUC as fair. Only 7% of participants found the account and device setup somewhat difficult, and none found it very difficult. More than half of the open-response comments were related to MRD installation and setup instructions.

Figure 16. Initial Survey Respondents

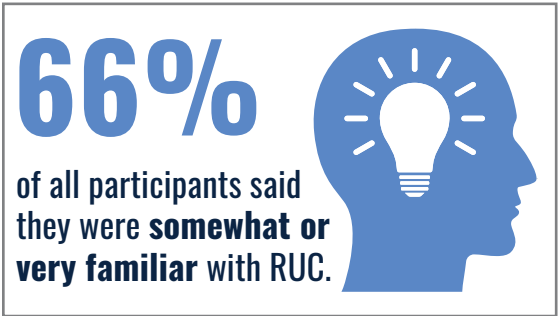


Younger and more educated participants reported higher levels of familiarity with RUC, with 66% of participants stating they were somewhat or very familiar with it. Those most familiar with RUC were typically between the ages of 26-45 and had at least completed some level of college (**Figure 17**). Women expressed greater comfort with sharing location information, with 97% of women being somewhat or very comfortable with this, compared to 69% of men. Overall, 78% of all participants were somewhat or very comfortable with providing their location data.

Most participants (70%) preferred to receive a combined tolling and RUC statement rather than individual statements for each.

Figure 17. Initial Survey Results on Familiarity with RUC

Younger and more educated participants noted **higher levels of familiarity** with RUC.



Age	Somewhat or Very Familiar	Somewhat or Very Unfamiliar
Under 18	100%	0%
18-25	66%	33%
26-35	73%	27%
36-45	71%	29%
46-55	61%	38%
56-65	60%	40%
66-75	66%	33%

Participants aged 26-45

School Completed	Somewhat or Very Familiar	Somewhat or Very Unfamiliar
Less than HS	-	-
High School/GED	38	63
Some College	75	25
Associate's Degree	71	29
Bachelor's Degree	74	26
Graduate or Professional Degree	64	36

Participants with at least some college

5.2 POST-PILOT SURVEY

The post-pilot survey focused on changes in attitudes about the fairness of both State and local RUC, and changes in their level of comfort providing location information to support the local RUC and tolling. It also assessed participants’ understanding of and the accuracy of their RUC and tolling charges both in the web portal and in the combined statements and their overall experience in the pilot.

The post-pilot survey received 88 responses, representing about 82% of active participants. Several insights were gathered during the post-pilot survey regarding participants' experiences and perceptions of an RUC. First, 65% of participants reported that their understanding of a road usage charge increased due to the pilot. Additionally, nearly 8 in 10 participants believed it is fair or very fair for cities to implement a local RUC. Comfort with sharing location data also grew during the pilot (**Figure 18**).

Furthermore, the preference for a combined tolling and RUC statement increased significantly, from about 70% before the pilot to approximately 90% after. During the pilot, 96% of respondents viewed their monthly statement at least once, and almost half (46%) of respondents viewed their statement at least five times during the six-month pilot (**Figure 19**). Regarding the accuracy of the mileage and toll charges in their monthly statements, most participants were satisfied. Specifically, 77% felt their mileage charges were accurate, while 23% did not know or could not remember. For toll charges, 82% reported accuracy, with 18% uncertain. Notably, no participants reported their mileage or toll charges as being inaccurate.

Figure 18. Survey Results on Comfort with Sharing Location Data

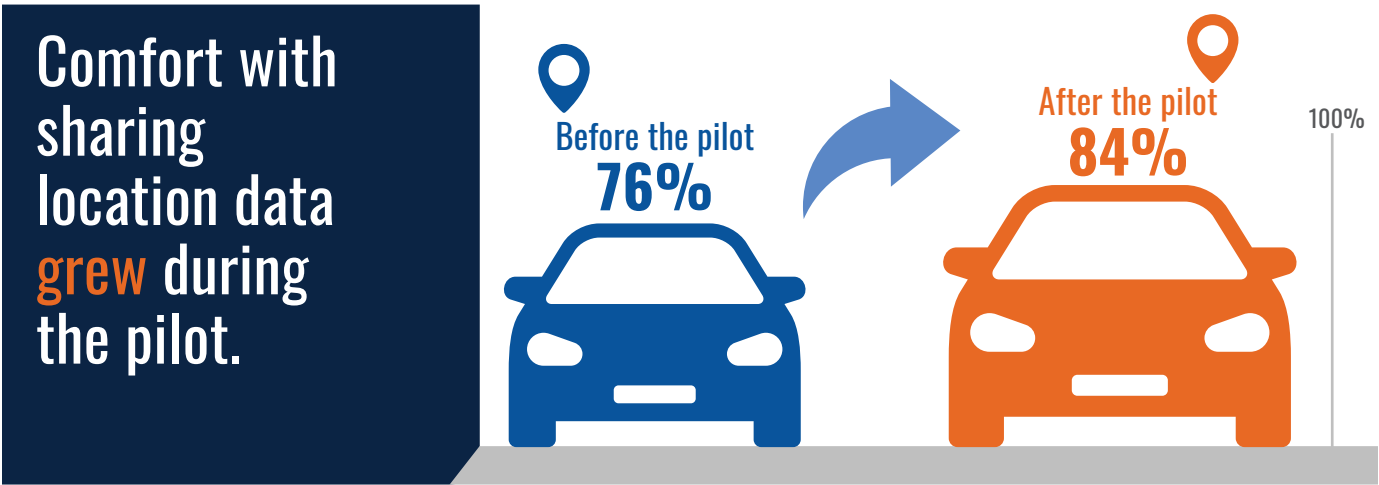
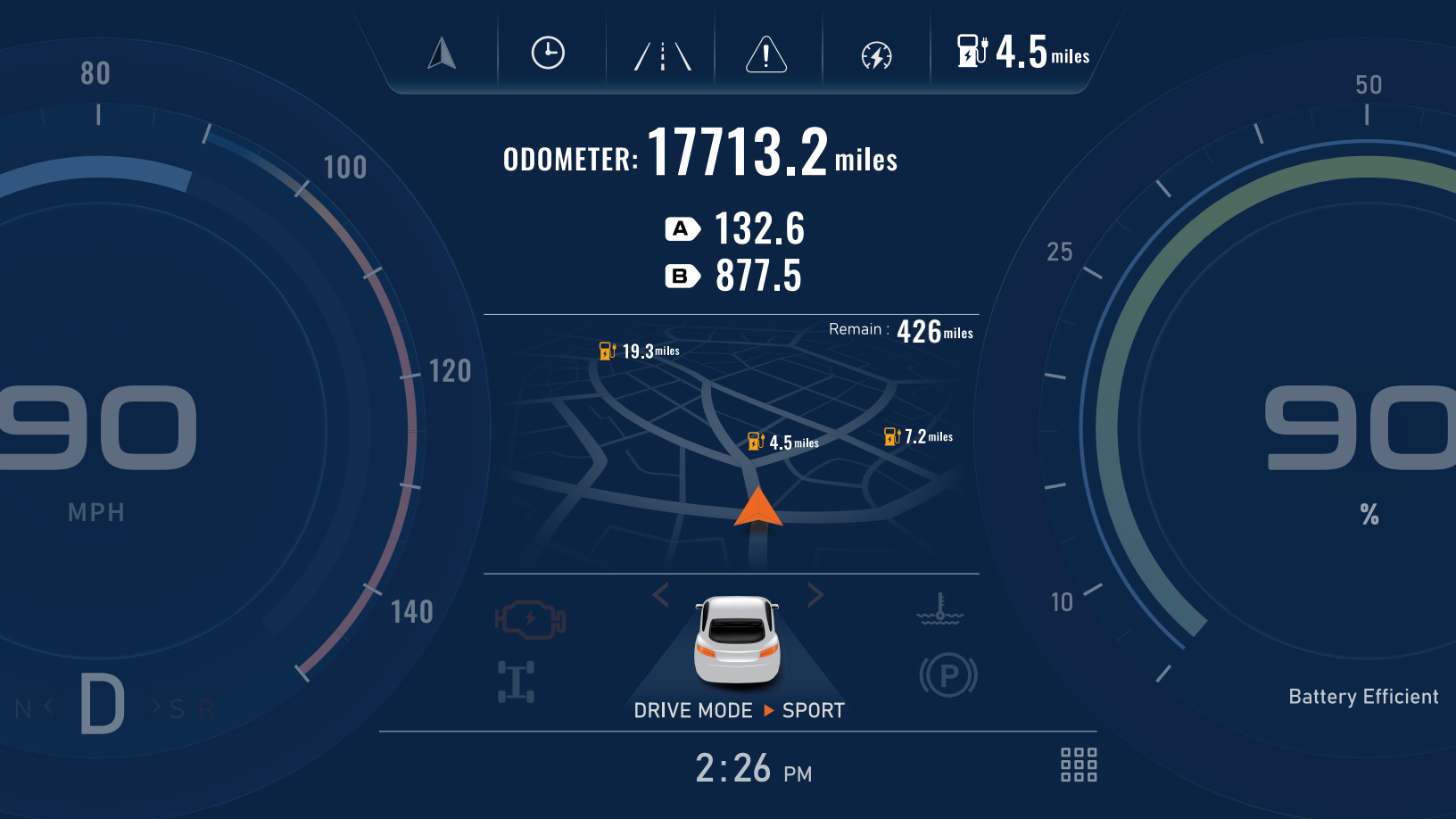


Figure 19. Survey Results on Combined Statements



SECTION 6.0

PILOT FINDINGS



6.0 PILOT FINDINGS

This section summarizes the pilot findings and how they addressed the two pilot goals as identified in Section 2.1.



6.1 GOAL 1: DEMONSTRATE THE INTEGRATION OF RUC WITH EXPRESS LANES TOLLING

Objective A: Demonstrate a combined tolling and RUC web portal and combined tolling and RUC monthly statements; show that both tolling and RUC charges can be displayed to users on a single web portal and on combined monthly statements.

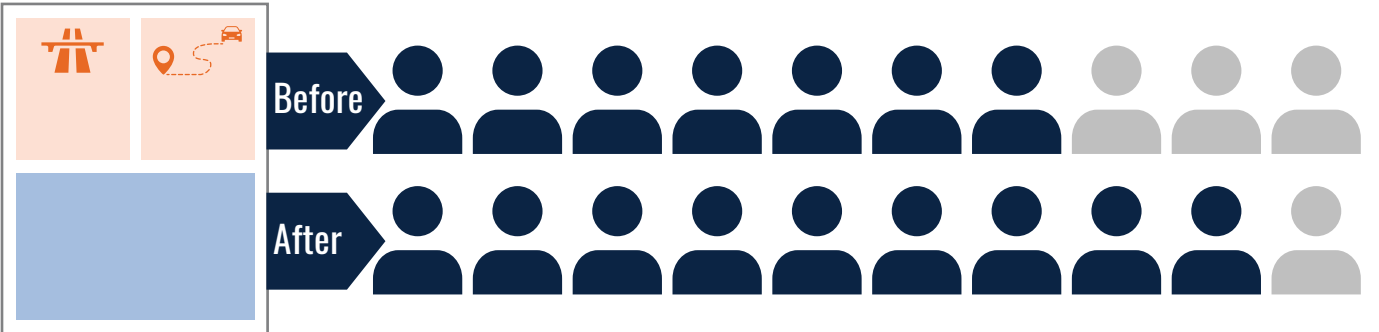
The Local RUC and Tolling Integration Pilot partially met this objective. The pilot demonstrated a combined tolling and RUC web portal quite effectively, and it showed that it was possible for participants to view both their RUC and tolling transaction details.

In addition, pilot participants were able to receive combined statements that showed totals for their state RUC, local RUC, and tolling charges. As shown in **Figure 20**, about 90% of participants revealed they preferred the combined statement, up from 70% at the beginning of the pilot. Also, about 9 in 10 participants who viewed their monthly statements said they were somewhat or very easy to understand.

However, the CAM was unable to modify the statement to include transaction level information for Express Lane usage and starting and ending wallet balances due to limitations of their system provided for the pilot. More detailed information on the monthly charges, wallet balance, and individual trips and transactions was available to participants through the web portal. Survey results indicated 62% of people accessed their online account during the pilot. About 96% of those that accessed their online portal found it easy or somewhat easy to use, and 91% felt it provided a clear breakdown of all transactions including state RUC, local RUC and tolling charges.

Figure 20. Preferences on Combined Statements

Even more participants preferred a combined tolling and RUC statement after the pilot.



Objective B: Demonstrate a combined tolling and RUC simulated wallet, a single electronic storage of simulated funds from which RUC and tolling transactions can be made. Show that both tolling and RUC charges can be deducted from a single electronic simulated wallet, and explore appropriate values for funding the simulated wallet.

The pilot showed that it was possible to maintain one wallet for RUC and tolling charges and for the system to deduct funds from the wallet incurring tolling and RUC transactions.

Even in a limited pilot, it was evident that the usage of the funds varied significantly across the participants. Some participants' wallets were replenished 4 to 5 times a month and some wallets were replenished 1 to 2 times a month. The minimum balance threshold and replenishment amounts should be recalculated based on system usage, and the system should be designed to have the ability to adjust replenishment amounts automatically based on usage. Replenishment amounts should be set such that wallets are replenished only 1 to 2 times a month to minimize the credit card fees.

Objective C: Determine what elements are necessary for automated tolling using RUC mileage reporting options (location reporting with lane determination to a specific degree of accuracy and enforcement paradigm changes).

The location reporting option should be accurate to distinguish travel between Express Lanes and general-purpose lanes in order for it to be used for automated tolling. The pilot demonstrated that the GPS accuracy of the MRD devices utilized in the pilot does not have this capability. However, the proof-of-concept test showed that GNSS-enabled telematics technology does offer this ability and can be used to capture both RUC and tolling transactions.





6.2 GOAL 2: DEMONSTRATE RUC LOCAL OVERLAY

Objective A: Work with localities to determine a RUC Local Overlay rate for each locality for the pilot, a very rough approximation for the amount that would cover the cost of the maintenance of locally maintained roadways if 100% of light vehicles were paying RUC.

UDOT contacted key stakeholders in each of the participating cities before the pilot and maintained contact throughout the pilot. UDOT shared the process by which the local RUC rate, unique to each city, was arrived at. This is a reasonable approximation for how the rate would work when applied over the totality of a city's street mileage.

Local RUC Rates Calculated as:

$$\frac{\text{Total Cost to Maintain Local Roads}}{\text{Vehicle Miles Traveled on Local Roads}}$$

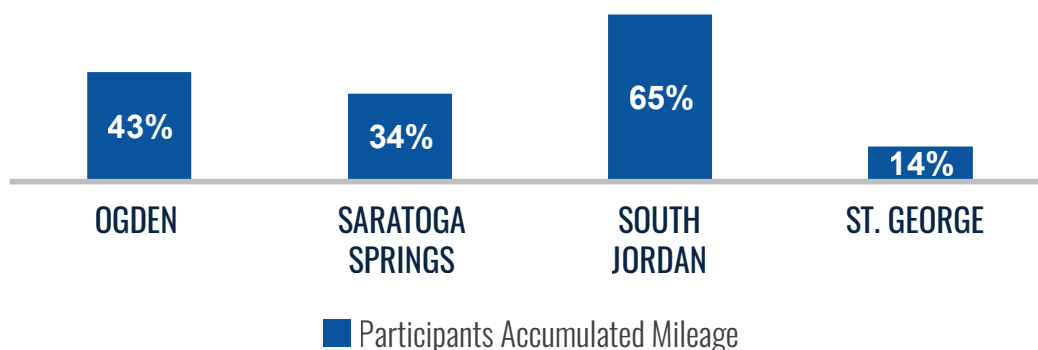
Objective B: Demonstrate the data collection and mapping needs (if any) to apply RUC Local Overlay Charging (location data indicating use of locally maintained roads in a given jurisdiction).

The pilot demonstrated that the GPS-enabled MRD could collect mileage data and distinguish travel in different local jurisdictions (**Figure 21**) and could be used to:

- Assess RUC with different rates in each local jurisdiction
- Report RUC charges by local jurisdictions

UDOT provided the geographic boundaries/GIS coordinates/geofence of each zone and the list of state-maintained roads in each zone. These maps were simplified to ensure correct RUC alignment with required jurisdictions by creating geofences around the city boundary and then around the state routes within each city boundary. Anything inside the city boundary geofence but outside the state route geofences was assessed the local RUC rate.

Figure 21. Percent of participants who traveled in at least one jurisdiction



Objective C: Establish RUC partnerships with local government agencies and demonstrate application of RUC Local Overlay charges based on data.

UDOT kicked off the pilot effort by meeting with each of the four participating cities and continued coordination throughout the project. In addition, UDOT coordinated with each of the participating cities on targeted recruits within their respective cities to ensure they could experience the pilot firsthand and provide any feedback after the pilot concluded.

The pilot demonstrated that RUC Local Overlay was accurately assessed across the four cities. **Table 16** shows the local RUC charges accrued in each city over the six-month pilot based on the mileage data collected. At the conclusion of the pilot, approximately 80% of participants thought it was fair or very fair for cities to charge a local RUC.

Table 16. Local RUC Charges by Jurisdiction

Month	Ogden		Saratoga Springs		South Jordan		St. George	
	Miles	RUC Charge \$0.006/Mile	Miles	RUC Charge \$0.007/Mile	Miles	RUC Charge \$0.007/Mile	Miles	RUC Charge \$0.007/Mile
Oct-23	1,170	\$7.02	1,021	\$7.14	1,415	\$7.07	190	\$0.76
Nov-23	2,101	\$12.60	1,962	\$13.73	2,908	\$14.54	1,012	\$4.05
Dec-23	1,842	\$11.11	2,152	\$15.07	2,997	\$14.99	1,669	\$6.67
Jan-24	2,102	\$12.61	2,005	\$14.03	3,164	\$15.82	1,135	\$4.54
Feb-24	2,185	\$13.11	1,950	\$13.65	2,911	\$14.56	739	\$2.96
Mar-24	2,174	\$13.04	2,152	\$15.06	2,817	\$14.09	740	\$2.96
Total	11,584	\$69.49	11,241	\$78.68	16,213	\$81.07	5,484	\$21.94



Today, local jurisdictions rely on B&C road funding to maintain and improve roads and streets within their borders. With fuel tax revenues declining as a result of more fuel-efficient and alternative fuel vehicles, the Utah Legislature continues to explore B&C alternatives to meet local transportation funding needs. This pilot showed that a RUC Local Overlay could provide local jurisdictions another option for funding road maintenance and improvements.

6.3 LESSONS LEARNED

6.3.1 RUC AND TOLLING INTEGRATION

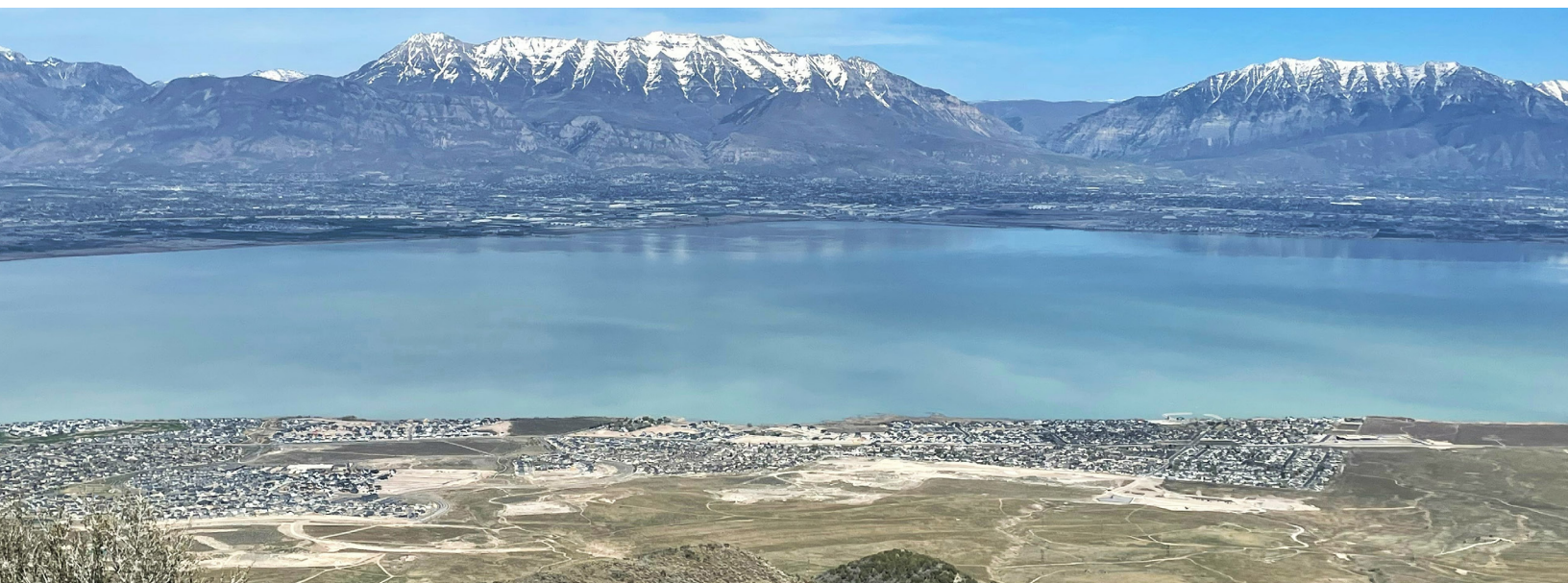
The integration of RUC with Express Lanes Tolling demonstrated several important lessons.

- Integrating tolling and RUC into a single web portal and monthly statement is a good concept and was highly favored by pilot participants as was revealed in the survey results.
- The combined wallet system, where both tolling and RUC charges are deducted from one account, functioned well.

The above two features demonstrated the viability of a combined account for RUC and tolling usage, which provided a positive user experience without the need for users to maintain two separate accounts. However, in order to have a fully integrated system, further functionality needs to be developed as follows:

- The back-office systems for tolling and RUC need to be combined into one system with interfaces to both roadside tolling system and road user charging devices.
- Ideally, one device should be used to capture both tolling and RUC transactions, while such devices are still under development and two separate devices are used, the back-office system should be capable of issuing devices for both tolling (e.g., transponder) and mileage collection (e.g., MRD).

This integration will result in reduced system costs as well as ongoing administrative and operations cost. In the future, these systems could be expanded to include other transportation charges such as parking, transit, EV charging, bike rental, etc., providing the users with one transportation account and wallet for all their transportation needs.



6.3.2 USE OF MRDS FOR RUC AND TOLLING

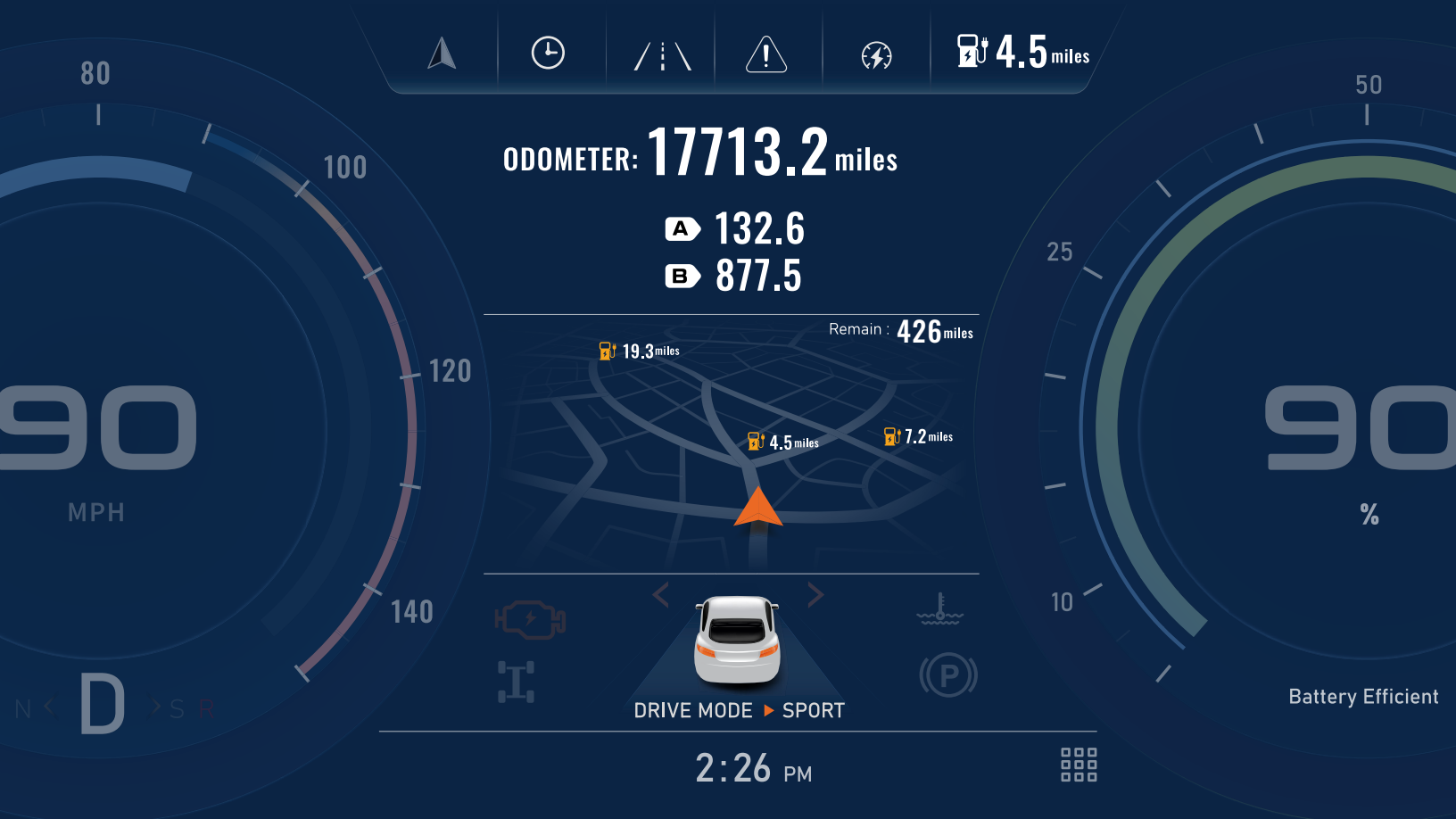
The GPS-enabled MRDs worked well to capture location information and measure distance traveled accurately. The system reported travel by jurisdiction and calculation of RUC using different rates by jurisdiction accurately, however the MRDs used in the pilot did not have the ability to report travel in Express Lanes. In addition, some problems were encountered during pilot operations with the MRDs:

- Bulkiness of the device, which made it difficult to properly install it in the vehicle resulting in installation/activation issues.
- Device was easily shaken loose in the OBD-II port, resulting in low stability of the device for some users. A zip tie was required to maintain stability in the vehicle, which was difficult to install.
- Device was incompatible with several vehicles (14% of 198 vehicles) that wished to participate in the pilot.
- Four customers reported that the device drained their battery and asked to be removed from the pilot to avoid further issues.
- Finally, the Geotab MRD could not be used for automated tolling due to accuracy issues.



APPENDIX A

VERRA MOBILITY CONNECTED VEHICLE PILOT FINAL REPORT





Connected Vehicle Pilot

CDM Smith – Utah Express Lanes

June 2024

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Connected Vehicle (CV) Pilot Overview

Background

The UDOT Local Road Usage Charge (RUC) and Tolling Integration Pilot is exploring how to combine a road usage charge with tolls accrued in the I-15 Express Lanes. Specifically, UDOT wants to understand how to provide tolling charges, state road usage charges, and local road usage charges in a single monthly statement. The pilot objectives included the following:

- Objective A: Demonstrate a combined tolling and RUC web portal, and combined tolling and RUC monthly statements—show that both tolling and RUC charges can be displayed to users on a single web portal, and on combined monthly statements.
- Objective B: Demonstrate a combined tolling and RUC simulated wallet, a single electronic storage of simulated funds from which RUC and tolling transactions can be made. Show that both tolling and RUC charges can be deducted from a single electronic simulated wallet and explore appropriate values for funding the simulated wallet.
- Objective C: Determine whether automated tolling using mileage reporting device is feasible.

The pilot launched October 1, 2023 and operated through March 2024. The pilot was able to test Objectives A and B outlined above. However, the pilot vendor informed UDOT that their preliminary testing showed that the plug-in device selected for the pilot (Geotab OBDII) could not be used for lane level-accuracy to distinguish trips in the Express Lanes versus driving in the adjacent lane.

UDOT wanted to conduct a proof-of-concept to test if there is technology in the market that could provide this functionality and accuracy needed to collect both tolls in Express Lanes adjacent to General Purpose Lanes and collect mileage data for a road usage charge.

UDOT, through CDM Smith, partnered with Verra Mobility to conduct a proof-of-concept test using telematics (utilizing Global Navigation Satellite System [GNSS] technology) with the following assumptions:

1. The test would be done to only capture tolling transactions. It is assumed that the mileage collection by location capabilities of the GNSS technology has been tested elsewhere.
2. The test would be conducted over two weeks.
3. The proof-of-concept participants would be limited to 2-5 vehicles.
4. Verra Mobility would be asked to provide only the toll transaction data in a pre-determined format.
5. For comparison with road toll transactions, data from the I-15 Express Lanes transponder and toll account will be utilized.

Telematics Setup for the Pilot

In collaboration with CDM Smith, Verra Mobility explored the concept of leveraging connected vehicles and GNSS technologies to create new and secure ways to charge and collect a toll.

Topics under study included the ability to properly identify a toll transaction without roadside infrastructure by leveraging connected vehicle technology. The pilot also leveraged dynamic factors such as location information, and vehicle occupancy through a connected vehicle.

Connected Vehicle Pilot Goals:

CDM Smith and Verra Mobility worked together on the proof-of-concept test to evaluate if transaction information from telematics could be used as a proxy to transponder readings in 1-15 Express Lanes in Utah.

The high-level objectives of this proof-of-concept test included:

- Demonstrate the ability to properly identify a toll transaction leveraging connected vehicle technology to determine the appropriate toll charge
- Match a transponder transaction captured with a corresponding Connected Vehicle toll transaction
- Assess the completeness of information received from a connected vehicle toll transaction to process a toll payment
- Provide comprehensive data to aid in trip building by capturing data from all toll points

Automatically detect and record vehicle occupancy and validate eligibility for HOV lane usage or apply relevant rates

Connected Vehicle Pilot

The Connected Vehicle Pilot was conducted on I-15 in UDOT's Express Lane toll facilities. It leveraged Automotive (OEM) embedded connectivity to collect information from the vehicle's telematics.

Connected Vehicle Toll Transaction

This demonstration focused on two primary goals. First, was the ability to replicate the traditional method of generating a toll transaction record by leveraging the connected vehicle data to emulate the data collected through roadside infrastructure. As shown in Table 1, a variety of roadside infrastructure is needed to identify the vehicle, determine the lane in which vehicle is travelling, classify the vehicle, determine vehicle occupancy and vehicle weight. All this information could be gathered through the sensors embedded in the vehicle and communicated using telematics.

Table 1: Summary of Data Collected through Roadside Infrastructure and Connected Vehicle

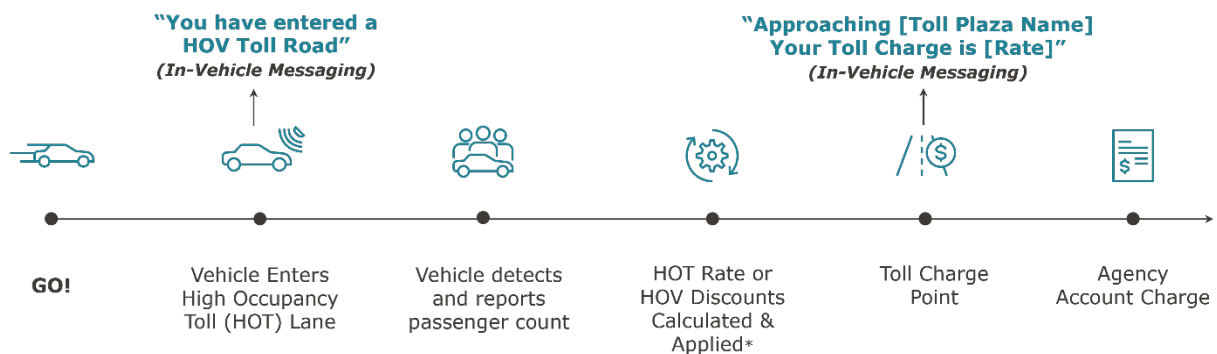
Function	Roadside Infrastructure					Connected Vehicle/ Embedded Telematics
	Readers	Cameras	Signage	Classification Sensors	WIM	
Vehicle Identification	X	X				X
Lane determination	X	X				X
Vehicle Classification		X		X		X
Occupancy Detection		X				X

Function	Roadside Infrastructure					Connected Vehicle/ Embedded Telematics
	Readers	Cameras	Signage	Classification Sensors	WIM	
Weight					X	X
Rate Communication			X			X

In this demonstration, the vehicle was detected and identified upon entering a tolling facility using GNSS data and telematics within the vehicle. As tolls gradually accumulate throughout the journey, the vehicle operator is promptly informed of each toll charge through the in-vehicle infotainment screen, ensuring continuous transparency.

Second, the passenger detection data sourced from within the vehicle was captured to demonstrate that the toll rates could result in an adjusted toll charge that reflects the advantageous high occupancy rate, provided the conditions for this rate are met and applicable to agency policy (see Figure 1).

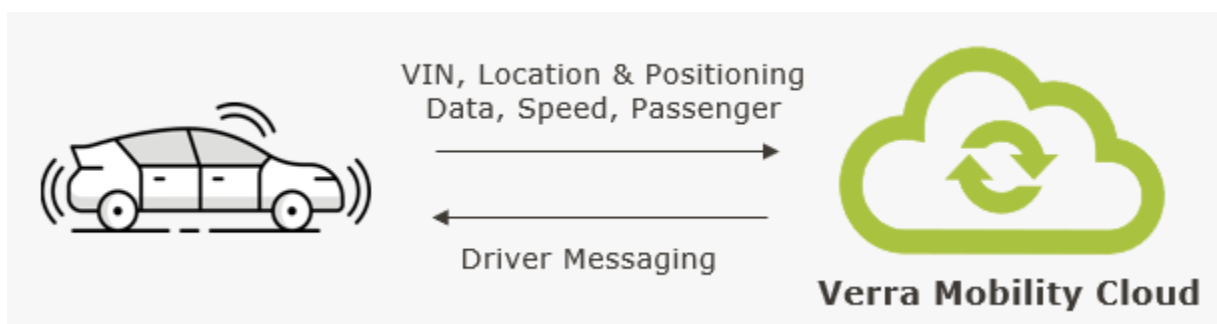
Figure 1: Connected Vehicle Journey



Connected Vehicle Technical Architecture

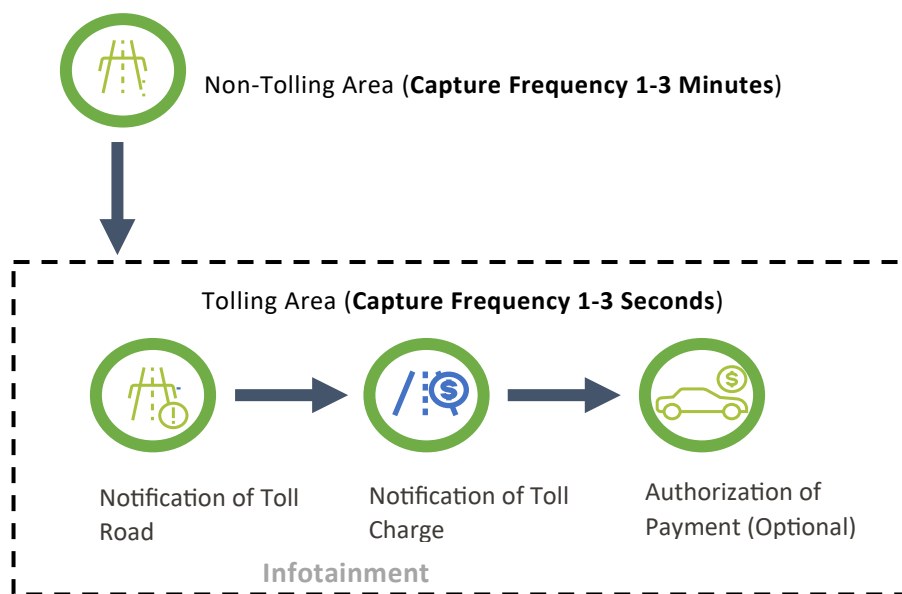
The Verra Mobility Connected Services platform, AutoKinex, is a cloud-based architecture that requires no roadside infrastructure or hardware implementations. The vehicle on the road is tracked using the on-board telematics and there is continuous communication of data between the vehicle and AutoKinex platform.

Figure 2: AutoKinex Connected Services Platform Architecture Diagram



To capture toll transactions, geo-fences are created around the toll entry and exit point locations in the AutoKinex platform. Once a vehicle is enrolled in the program the AutoKinex system receives data every 1 -3 mins from the vehicle until it nears a geo-fence location. As it enters a geo-fenced region, the data transfer frequency increases to 1-3 seconds. The AutoKinex platform takes the vehicle telematics data and uses proprietary algorithms to match coordinates and identify a toll transaction and apply the correct rates. Consequently, a toll alert message is sent back to the vehicle through the AutoKinex platform which is displayed on the in-vehicle infotainment screen. Finally, at an established period all the identified toll transactions are reconciled and sent to the agency for processing.

Figure 3: AutoKinex Connected Services Platform Data Collection and Messaging Diagram



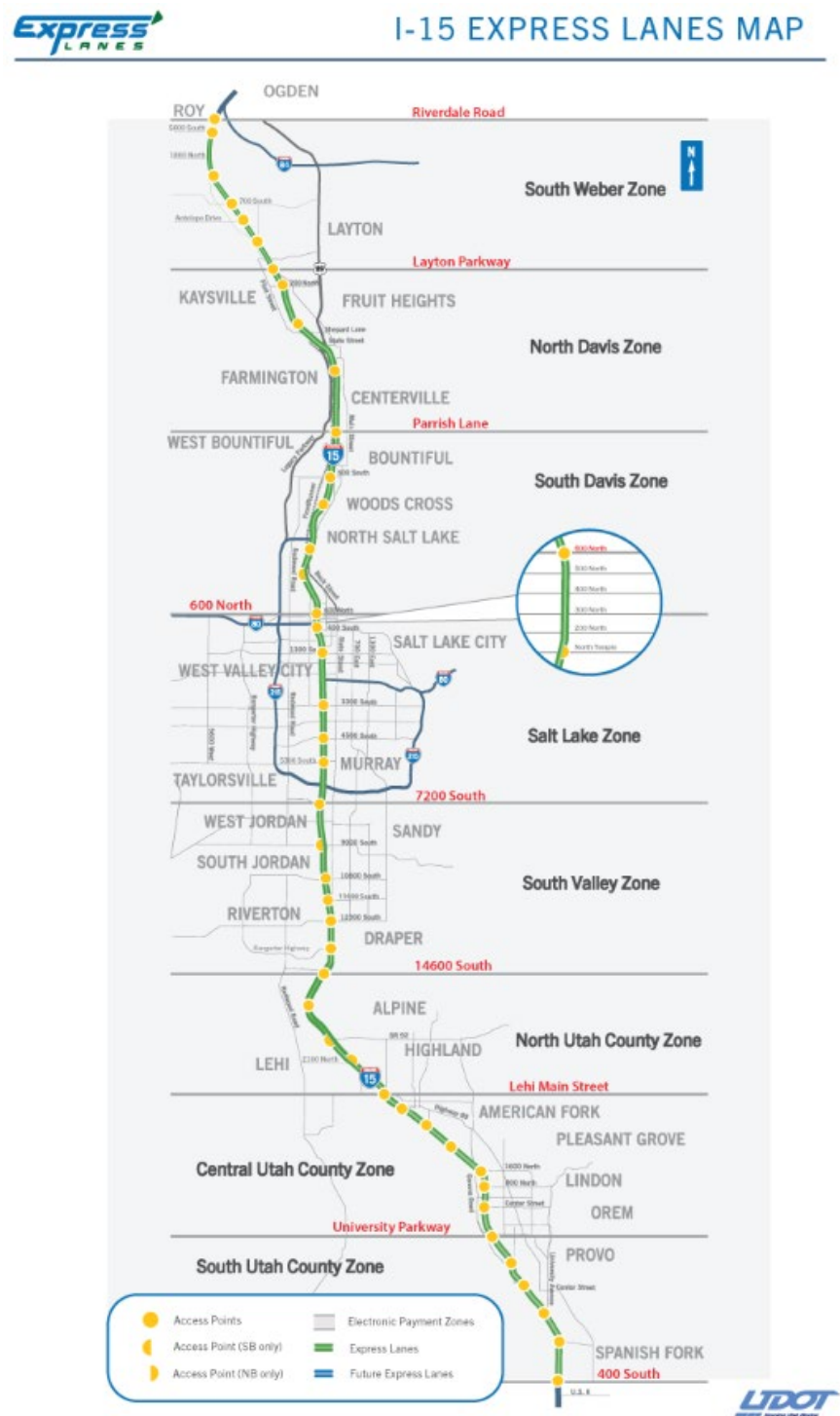
Connected Vehicle Tolling Methods and Approach

Toll Methods

This Connected Vehicle Pilot focused on evaluating the feasibility of using GNSS data for tolling on UDOT I-15 Express Lanes. The test area is shown in Figure 4. Onboard vehicle telematics were leveraged to capture vehicle movement throughout the two-week test period.

The project aimed to assess the accuracy and effectiveness of GNSS-based tolling through various test scenarios. While the overall solution incorporates rate calculations for toll transactions, this aspect was excluded from the pilot's scope. UDOT expressed primary interest in testing the capture of toll events using GNSS data, considering their existing dynamic pricing structure.

Figure 4: UDOT Express Lanes Network/Connected Vehicle Pilot Test Corridor



Tolling Test Vehicles and Equipment

The three vehicles shown in Table 2 were used for the field testing. All three vehicles used the OEM onboard telematics and infotainment systems.

Table 2: Connected Vehicle Pilot Vehicles

OEM Telematic Integrations: Stellantis			
Vehicle	Plate	Transponder ID	Telematic Method
Jeep Grand Cherokee	L0A4TR-AZ	1C4RJYB63P8786473	OEM Direct Embedded Connectivity
Jeep Grand Cherokee	LWA1TR-AZ	1C4RJYB66PC610739	OEM Direct Embedded Connectivity
RAM 1500	T417SB-UT	1C6SRFLT2PN548089	OEM Direct Embedded Connectivity

Occupancy

Vehicle occupancy was established through passenger detection by the OEM embedded systems using sensors in the seats.

Messaging and Response

Messaging through the in-vehicle infotainment screen was deployed to alert the vehicle operator for notification of a toll area network, and a toll charge, when it occurred (see Table 3). In two use cases, Automated Toll Account Enrollment and One-Time Toll, the vehicle operator was required to respond with consent and/or authorization.

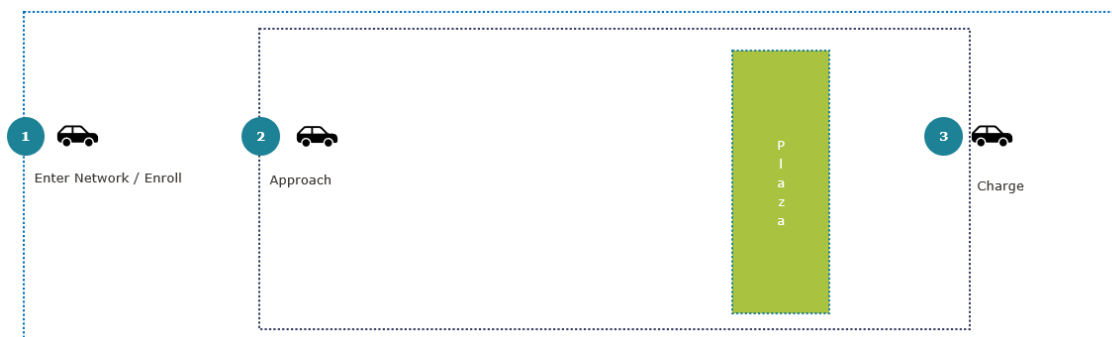
The vehicle operator is prompted that they are entering a toll facility, and they have the option to either open an account for current and future use or just pay for the current toll for using the facility. These in-vehicle messages could be programmed to show any relevant information about the transaction.

Table 3: Method of Messaging and Response

Vehicles	Message and Response Method
Vehicle 1	In-Vehicle Infotainment System
Vehicle 2	In-Vehicle Infotainment System
Vehicle 3	In-Vehicle Infotainment System

Figure 5 shows the messaging flow.

Figure 5: In-Vehicle Messaging Flow



Test Scenarios

Table 4 summarizes the four test scenarios evaluated in the UDOT Connected Vehicle Pilot.

Table 4: Connected Vehicle Pilot Test Scenarios

Test Case	Description	Test Method	Expected outcome
Express Lane Tolling	Driving on the HOV Toll lane with no passengers	Drive along the full stretch of the HOV Express Lane NB/SB	The GNSS captures match the toll transactions read by the transponder
Toll lane proximity testing	Driving on the general purpose lane adjacent to the HOV Toll lane	Drive very closely on the lane to the right of the HOV Toll lane, along the full stretch of the Express Lane NB/SB	There should not be any toll transaction captured through GNSS data
Occupancy testing	Driving on the HOV Toll lane with a passenger (2+ configuration)	Drive along the HOV lane with 2 people in the vehicle.	The vehicle data indicates 2 occupants in the vehicle and notifies the system that the vehicle qualifies for HOV rates.
Toll Evasion	Driving in a way such that a transponder read is avoided at the gantry	Driving on the HOV Toll lane until reaching a toll gantry and then jumping lanes to avoid a toll capture	The GNSS data captures the path taken by the vehicle on the HOV Lane and identifies lane usage and calculates toll charge accordingly, even if the vehicle evades toll gantry.

Connected Vehicle Pilot Evaluation Results

Using vehicle data in conjunction with a connected vehicle platform, without interfacing with the roadside tolling infrastructure or back office, the initial testing was able to demonstrate very strong success rates at identifying the various data points and responding to those events consistently (see Table 5).

Table 5: Connected Vehicle Pilot Accuracy Results

Demonstration	GNSS Toll Accuracy
Accurate Identification of the Vehicle	100%
Accurate Identification of Relative Location for Toll Transaction*	94%
Accurate Lane Determination	97.5%
Accurate Vehicle Classification	100%
Accurate Detection of High Occupancy Passengers	100%
Accurate Messaging and Response – Toll Transaction	100%

**Result of unexpected OEM Software release during the pilot, caused accuracy to be lower.*

Observations

Even though this pilot successfully demonstrated the accuracy and efficacy of a GNSS-based tolling system, a few anomalies were observed -

1. GNSS missing transactions –

There were instances where the GNSS transactions were missed at the toll gantry location due to the coordinates being outside the geo-fenced area. This could be a result of several factors, like the curvature of the road or GPS drift.

This issue was rectified through a combination of counter-measures –

- a. Course correction algorithms to account for directional GPS drift
- b. Recalibration of geo-fence coordinates and area definition based on extensive data mapping

2. Temporary loss of connectivity –

This was a result of sporadic network issues between the vehicle and the cloud infrastructure. Although this is not as common, it may impact data processing sporadically.

The following solutions are being implemented for this issue –

- a. Dead reckoning of GPS coordinates when there is a temporary loss of communication
- b. Queuing of data at the time of network loss and upload of queued data to back-end systems once network connectivity is restored

3. OEM software issue –

During the testing period of the pilot program, an unknown defect was discovered in the OEM software when the peripheral interface hardware was used in a specific configuration. This issue caused a temporary breakdown in communication between the OEM GNSS component and backend cloud services resulting in missed GNSS data captures.

The issue was addressed by the following actions –

- a. The defect was reported to and resolved by the OEM
- b. Avoided usage of the impacted interface component for the rest of the pilot testing period

Connected Vehicle Pilot Conclusion

Using GNSS for tolling and road usage charging is an efficient method for road pricing. It is based on a vehicle's travel details and other important automotive data such as odometer readings, fuel type, classification, and passenger occupancy detection.

The subsequent detail highlights a selection of innovative capabilities that were not only incorporated but also effectively demonstrated during this pilot.

GNSS Tolling Pilot

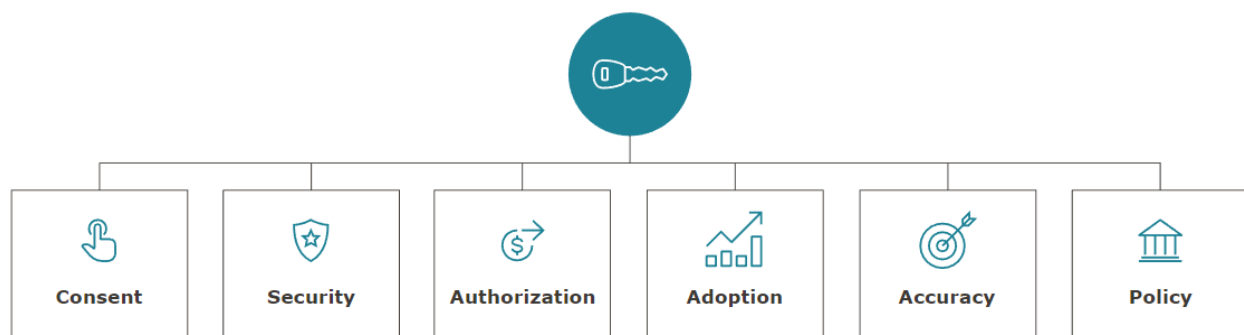
The objectives set forth in this pilot study were successfully completed. It was demonstrated that GNSS data obtained from a connected vehicle could be used to capture toll transactions on Utah I-15 Express

Lanes. GNSS tolling offers several advantages over traditional hard infrastructure tolling systems. For instance, it provides flexibility and efficiency without the need for additional toll booths or physical infrastructure on the roads, reducing costs and minimizing traffic disruptions. These solutions could also be easily adjusted, allowing for dynamic pricing models to effectively manage road usage.

However, there are challenges to implementing GNSS tolling. Privacy is a major concern as the system inherently tracks vehicles' movements. Ensuring that the system is secure, reliable, and accurate is important, as is finding a fair and effective way to handle non-compliant users.

Before any potential consolidation or retirement of today's traditional infrastructure, several key considerations need to be addressed as shown in Figure 6.

Figure 6: Key Considerations for GNSS Tolling



- Consent – People are very protective over their data until there is a greater value of convenience than there is to privacy, so there needs to be an opt-in process.
- Security – If you build it, they will try to hack it. There are continued advancements in vehicle cybersecurity. Questions to consider is who decides the security requirements- Toll Agencies, OEMs, Owners, and what combination.
- Payment Authorization – Consistent with all things purchased and paid for online, authorization of charges to be paid must be built into the model.
- Accuracy - For financial applications like tolling, lower levels of system performance and accuracy are not acceptable.
- Reliability – The system needs to provide high availability, consistent and measurable results in all conditions with redundancy where needed to ensure the complete data and auditability.
- Policy – Consider what policy changes might prohibit leveraging C-V2X capabilities and will authorization and consent from vehicle owners play a key role in the enablement. Currently, it is required that the vehicle owners have an OEM telematics subscription (for a fee in some cases) and provide their consent to share data.

This pilot highlighted various use cases that effectively demonstrated how Connected Vehicles and GNSS technology could be incorporated. These applications could immediately add value for Toll Authorities by

complementing existing systems. They could notably improve the adjudication process for Image-Based Transactions (IBT), which is often associated with high costs.

By embracing GNSS solutions early on as a complementary component to existing Toll Systems, agencies have the opportunity to explore and experiment with the future trajectory of tolling without the fear of financial risk, creating a secure environment for innovation.

This progressive approach also sets the stage for enhancing in-house expertise related to these solutions. As the adoption of such technology increases, it could yield incremental value, fueling the constant evolution and improvement of tolling systems.

Recommendations and Additional Explorations

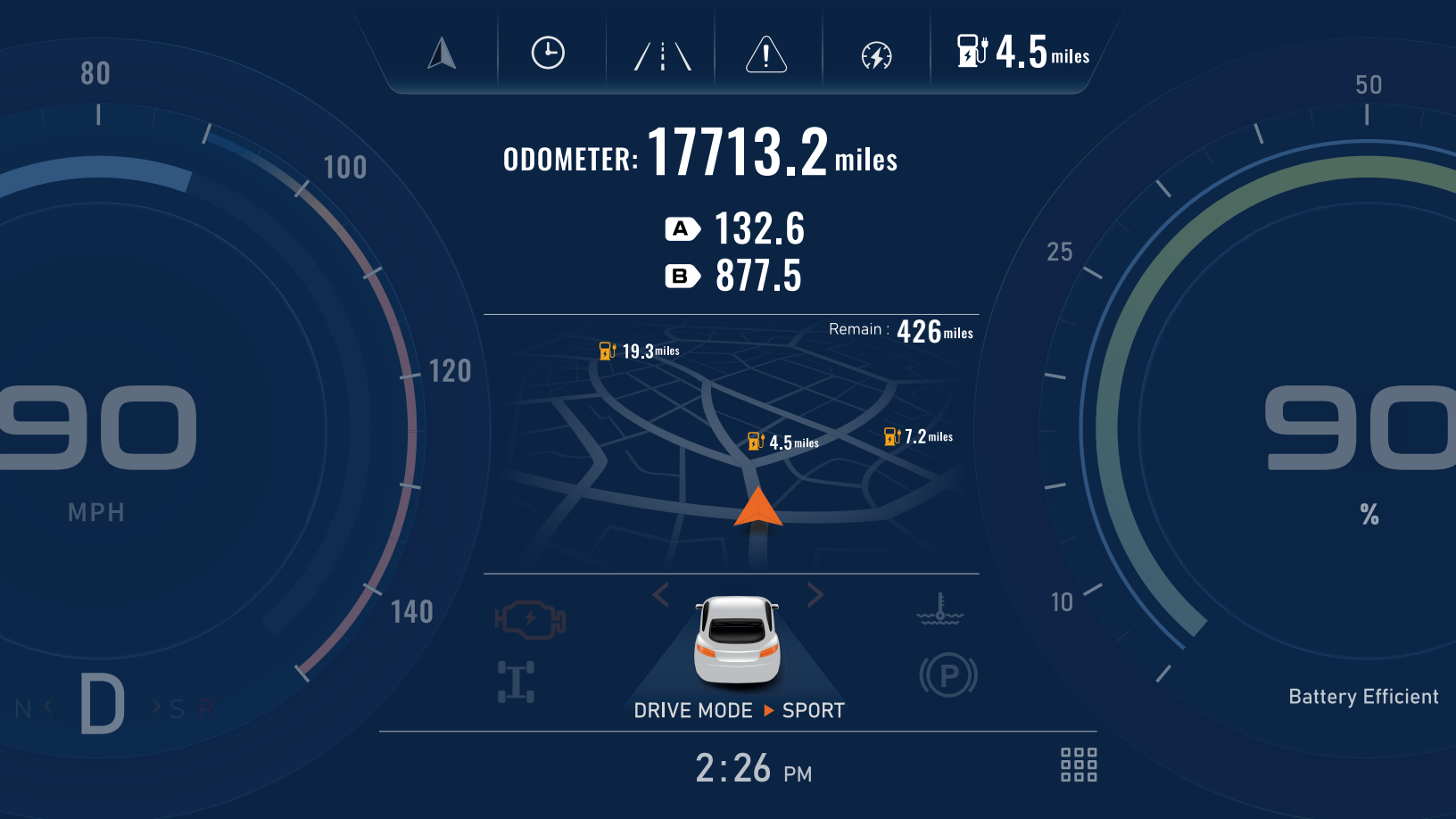
After conducting the pilot and reviewing the results, we recommend performing an expanded pilot with additional participants. This will provide an opportunity to evaluate the full potential of Connected Vehicle tolling in a scaled scenario. It will also provide the opportunity to make the necessary changes to toll location geo-fences and operate with greater performance after the implementation of required software updates to the vehicles (as was experienced during the pilot).

Connected Vehicles enable UDOT to do lot more than Express Lanes Tolling, including HOV detection, making full use of the capabilities of data collection and in-vehicle messaging. Some of the use cases included:

- **Road Usage Charging (RUC):** Connected vehicles provide an easy and non-intrusive way of capturing vehicle miles data for a RUC program. The benefits of using embedded telematics as opposed to an after-market device is that it greatly reduces the possibility of errors and fraud, while improving the accuracy and breadth of data collected. There's also the added benefit of the ability to gather more GNSS data and implement RUC zone requirements to apply appropriate rates.
- **Work Zone Notifications:** Using the in-vehicle messaging, UDOT could setup work zone geofences to automatically send in-vehicle messages to drivers alerting of construction areas and speed restrictions. This could improve road safety and better traffic management.
- **Weather and Traffic Alerts:** The in-vehicle messaging could also be used to alert drivers of impending weather conditions and traffic issues. This will promote safe driving and allow drivers to plan for road conditions.

APPENDIX B

PARTICIPANT SURVEYS



Initial Survey

Initial Survey

Thank you for participating in the UDOT Local Road Usage Charge (RUC) and Tolling Integration Pilot. Your participation in this survey is an important part of exploring new approaches to transportation funding, how to improve the driver payment experience, and reduce costs for payment collection.

To earn the \$100 incentive you must complete both this survey and a second survey that will be administered upon completion of the pilot. We ask that you please answer all questions.

Pilot Enrollment and Setup

The following questions are about your UDOT Local RUC and Tolling Integration Pilot enrollment experience and participation so far.

1. Please provide the email address you are using for this pilot: _____
2. Why did you decide to participate in this pilot? Select all that apply.
 - a. The \$100 incentive
 - b. Free Express Lanes access
 - c. To have a better understanding of transportation policies
 - d. To provide input on local transportation policies
 - e. Other: _____
3. What additional information would have been helpful in advance of your enrollment in the pilot?
 - a. None. I had all the information I needed.
 - b. More information about what a road usage charge is
 - c. More information about how Utah's Road Usage Charge Program works and how it could be integrated with tolling
 - d. More information about how funds from road usage charges are used to maintain state roads and bridges
 - e. More information about the state and local road usage charges simulated in the pilot
 - f. Other: _____
4. How easy was setting up your Local RUC and Tolling Integration Pilot account?
 - a. Very easy
 - b. Somewhat easy
 - c. Somewhat difficult
 - d. Very difficult

4A) For people who respond "C" or "D" to Q4: What did you find difficult?

-
5. How easy was it to set up your mileage reporting device and/or your tolling transponder?
 - a. Very easy
 - b. Somewhat easy
 - c. Somewhat difficult

- d. Very difficult

5A) For people who respond "C" or "D" to Q5: What did you find difficult? Select all that apply.

- a. Setting up my tolling transponder
- b. Setting up my mileage reporting device
- c. Other: _____

6. What suggestions do you have for making enrollment easier?

Road Usage Charging

The following questions focus on the road usage charge concept in general, as well as your thoughts about combining state road usage charges with local road usage charges and tolling charges.

7. How familiar are you with the concept of a road usage charge?
- a. Very familiar
 - b. Somewhat familiar
 - c. Somewhat unfamiliar
 - d. Very unfamiliar
8. When vehicles fill up at the pump, they pay a per-gallon state gas tax, which is used to build and maintain state roads. Instead of a gas tax, Utah and some other states offer a road usage charge on certain vehicles in lieu of paying a registration surcharge. The road usage charge is based on miles driven rather than fuel purchased. In your opinion, how fair is the concept of a road usage charge compared to the gas tax?
- a. Very fair
 - b. Somewhat fair
 - c. Somewhat unfair
 - d. Very unfair

8A) For people who respond "C" or "D" to Q8: What do you think is most unfair?

- a. Unfair to people driving high fuel-efficient vehicles
- b. Unfair to people driving electric or alternative fuel vehicles
- c. Unfair to low-income individuals
- d. Unfair to rural drivers
- e. Other: _____

9. This pilot is evaluating both a state road usage charge and a local road usage charge. A state road usage charge would help fund state roads, while a local road usage charge would help fund city roads. How fair do you think it is for cities to charge a local road usage charge to help pay for city-maintained roads?
- a. Very fair
 - b. Somewhat fair
 - c. Somewhat unfair
 - d. Very unfair

10. This pilot uses a mileage reporting device to collect your location data and determine state and local road usage charges as well as tolling charges. How comfortable are you providing this information?

- a. Very comfortable
- b. Somewhat comfortable
- c. Somewhat uncomfortable
- d. Very uncomfortable

10A) For people who respond "C" or "D" to Q10: What makes you uncomfortable? Select all that apply.

- a. I'm concerned about government having my location data
- b. I'm concerned about the security of my data
- c. I'm concerned about my data being shared with others (e.g., police, insurance, etc.)
- d. Other: _____

11. During the pilot, each of your monthly statements will contain your tolling charges and your road usage charges. Do you like the idea of combining these charges into a single statement?

- a. Yes
- b. No – I'd rather get one statement for tolling charges and a different statement for road usage charges
- c. I don't know/don't care

Pilot Participant Profile

OPTIONAL: We're asking a few questions about you and your household to better understand how combining tolling charges and road usage charges could affect Utahns.

12. What is your age?

- a. 18-24
- b. 25-34
- c. 45-54
- d. 55-64
- e. 65-74
- f. 75+
- g. Prefer not to answer

13. Which of the following best describes your race and/or ethnicity? Select all that apply.

- a. American Indian or Alaska Native
- b. Asian
- c. Black or African American
- d. Hispanic/Latino
- e. Native Hawaiian or Other Pacific Islander
- f. White
- g. Prefer not to answer

14. Which of the following best describes your gender?

- a. Woman
- b. Man
- c. Other
- d. Prefer not to answer

15. What is your current employment status?

- a. Working full-time
- b. Working part-time
- c. Retired or not working
- d. Prefer not to answer

16. What is the highest degree or level of school you have completed?

- a. Less than high school
- b. Some high school
- c. High school graduate, GED, or equivalent
- d. Some college
- e. Associate's degree
- f. Bachelor's degree
- g. Graduate degree
- h. Prefer not to answer

17. What is your annual household income?

- a. Less than \$25,000
- b. \$25,000 to \$34,999
- c. \$35,000 to \$49,999
- d. \$50,000 to \$74,999
- e. \$75,000 to \$99,999
- f. \$100,000 to \$149,999
- g. \$150,000 to \$199,999
- h. \$200,000 or more
- i. Prefer not to answer

Post-Pilot Survey

Post-Pilot Survey

1. Do you feel you have a better understanding of a road usage charge as a result of the pilot?
 - a. Yes – I have an improved understanding of what a road usage charge is
 - b. Same – my understanding has not changed
 - c. No – I have less understanding of what a road usage charge is
2. This pilot is evaluating both a state road usage charge and a local road usage charge. A state road usage charge would help fund state roads, while a local road usage charge would help fund city roads. How fair do you think it is for cities to charge a local road usage charge to help pay for city-maintained roads?
 - a. Very fair
 - b. Somewhat fair
 - c. Somewhat unfair
 - d. Very unfair
3. This pilot used a mileage reporting device to collect your location data and determine tolling charges and mileage charges. How comfortable were you with providing this information?
 - a. Very comfortable
 - b. Somewhat comfortable
 - c. Somewhat uncomfortable
 - d. Very uncomfortable
4. Did you access your online account during the pilot (click [here](#) to access your account)?
 - a. Yes
 - b. No

4A If “Yes” answered to Q4: How easy was it to use your online account?

- a. Very easy
- b. Somewhat easy
- c. Somewhat difficult
- d. Very difficult

4B “If “Yes” answered to Q4: Which parts of your online account did you use?

- a. Dashboard
- b. Activity
- c. Vehicles
- d. Wallet
- e. Account
- f. Transactions
- g. Statement
- h. Replenishments

4B.1 If answered "Wallet" to Q4B: How easy was it to understand your wallet transactions for simulated tolling charges and road usage charges?

- a. Very easy
- b. Somewhat easy
- c. Somewhat difficult
- d. Very difficult

4B.2 If answered "Very or somewhat difficult" to 4B.1: What would have made it easier to use the wallet?

4C) If "Yes" answered to Q4: Did you feel your online account provided a clear breakdown of all your transactions (i.e., state road usage charges, local road usage charges, tolling)?

- c. Yes
- d. No

4C1) If "No" to Q4C: Which transactions were unclear? Select all that apply.

- a. My state road usage transactions
- b. My local road usage transactions
- c. My tolling transactions
- d. Other _____

5. Each month, we emailed you a monthly statement. How often did you review these statements?

- a. Never
- b. 1-2 times (Once or twice during the pilot)
- c. 3-4 times (About once every other month)
- d. 5-6 times (Almost every month or every month)

5A) For people who responded "Never" to Q5: Why didn't you look at the statements?

- a. I didn't have time
- b. I didn't know how to access the statement
- c. I didn't feel the need to review
- d. Other: _____

5B) For people who responded "B", "C", or "D" to Q5: Which of the following charges do you remember seeing on your monthly statement? Select all that apply.

- a. State road usage charge paid
- b. Local road usage charge paid
- c. Tolling charges paid

5C) For people who responded "B", "C", or "D" to Q5: How easy was it to understand the monthly statement?

- a. Very easy
- b. Somewhat easy
- c. Somewhat difficult
- d. Very difficult

5D) For people who responded "B", "C", or "D" to Q5: How did you access your monthly statement? Select all that apply.

- a. Via my online account
- b. Via the email attachment

5E) For people who responded "B", "C", or "D" to Q5: Did your mileage on the monthly statement look accurate?

- a. Yes
- b. No
- c. I don't know or don't remember

5E1) For people who respond "No" to 5E: What was inaccurate about the mileage on your monthly statement?

- a. The statement mileage was higher than I actually drove
- b. The statement mileage was lower than I actually drove
- c. The statement had incorrect information about my trip locations
- d. Other: _____

5F) For people who responded "B", "C", or "D" to Q5: Did your toll charges on the monthly statement look accurate?

- a. Yes
- b. No
- c. I don't know or don't remember

5F1) For people who respond "No" to 5F: What was inaccurate about the tolling charges on your monthly statement?

- a. I used tolls more often than my statement showed
- b. I used tolls less often than my statement showed
- c. Other: _____

5G) For people who responded "B", "C", or "D" to Q5: Did the statements provide the information you needed to understand your road usage charges and tolling charges?

- a. Yes
- b. No

5G1) For people who respond "No" to 5G: What additional information would have been helpful?

6. Did you use customer service during the pilot?

- a. Yes
- b. No

6A: If "Yes" to Q6: How satisfied were you with your customer service experience?

- a. Very satisfied
- b. Somewhat satisfied
- c. Somewhat unsatisfied

- d. Very unsatisfied

6B: If "Yes" to Q6: How did you contact customer service?

- a. Email
- b. Phone

7. If given the choice, how would you prefer to access customer service? (*Rank*)

- a. Via phone – Speaking to a live agent
- b. Via phone – Using an automated system
- c. Via the website – Chatting with a live agent
- d. Via the website – Chatting with an automated system

8. How easy was it to participate in this pilot?

- a. Very easy
- b. Somewhat easy
- c. Somewhat difficult
- d. Very difficult

8A) For people who respond "C" or "D" to Q8: What did you find difficult?

- a. Setting up my account
- b. Setting up my mileage reporting device
- c. Setting up my tolling transponder
- d. Other: _____

9. Did you like having your tolling and road usage charge statements combined into one document?

- a. Yes, I liked having my tolling and road usage charge statements in one document
- b. No, I would prefer to receive two statements – one for tolling charges and a separate one for road usage charges

10. How satisfied were you with your participation in this pilot?

- a. Very satisfied
- b. Somewhat satisfied
- c. Somewhat unsatisfied
- d. Very unsatisfied

11. Please share any additional feedback about the pilot here:
