Demonstration Phase 2: Technology Test Drive Test Report

June 2020

Hawaii Road Usage Charge Demonstration

with

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Executive Summary

This document describes the testing carried out for of Part 2 of the Hawaii Road Usage Charging Demonstration, publicly called the Technology Test Drive, a nine-month demonstration of three mileage reporting methods, with a target of approximately 2,000 vehicles statewide:

► Plug-in device with location, a device that plugs into vehicles data ports and has built-in GPS

► Plug-in device without location, a device that plugs into vehicles' data ports but does not contain any location-determination technology

► Odofoto, a smartphone application for recording vehicle odometer

In the Technology Test Drive, participants select a Mileage Reporting Method, drive, receive monthly or quarterly invoices called Road Usage Reports, and provide feedback via online surveys.

The objectives of testing for HiRUC Part 2 were to ensure that:

► Participants would have an outstanding User Experience

► Systems performed as expected, in a secure manner.

Due to the large number of passenger cars and other light-duty vehicles that are part of a commercial fleet, a Fleet Pilot was conducted in March 2021 to determine whether providing odometer readings through a file exchange is a more convenient option for fleet operators to comply with RUC than other methods tested to date. the that included fleet operators across the four Hawaii counties: City & County of Honolulu, Hawaii County, Kauai County and Maui County.

Testing Stages

Testing was carried out in four stages:

► **Unit Testing:** Testing at the software component or module level. Each component of the software (unit) was tested to verify that the detailed design for the unit has been correctly implemented.

► **Integration Testing**: Functional testing designed to test that all system interfaces function as expected.

► **End-to-End Testing (E2E),** including User Acceptance testing, tested scenarios that reflect business processes and customer journeys which mirror the end-state operation of the system.

► A **Small-Scale Operational Trial (SSOT)** was a small, soft launch of the systems with volunteer participants. SSOT focused on functionality and customer experience.

In addition to the tests above, there were a number of non-functional tests carried out to ensure the solution could meet the requirements of performance and data/cyber security. This document covers a summary and results of all four stages of testing.

The HiRUC Part 2 solution was designed as follows:

- ► Participants enroll with the HiRUC service provider, Azuga, and choose their Mileage Reporting Method (MRM), Plug-In Device (PID) [with or without location] or OdoFoto;

- ► Participants receive the PID in the mail and install it, or download and use the HiRUC Azuga Insight app to capture an initial reading of their odometer using the OdoFoto function;

- ► Participants drive as normal. Participants respond to notifications, to submit readings for OdoFoto participants; or if there is an issue, such as a PID no longer transmitting data to the vendor back office;

- ► The system vendor, Azuga, provides customer support, by email and telephone.

In order for Azuga to successfully complete Part 2 testing, each business rule and system requirement had to be shown to be met through self-certification or testing.

Testing for the Fleet Pilot went through separate software functionality testing, user interface testing, and a small scale operational testing.

Testing Timeline

- ► Unit Testing was conducted in October 2019 following the completion of system development/implementation. Some limited individual unit tests continued after October 2019. Unit testing was performed by Azuga.

- ► Integration Testing was completed in November 2019. This included regression testing, Business Rule (BR) and System Requirement Specification (SRS) testing, User Journeys and Road Usage Report (RUR) generation. Integration testing was performed by Azuga and Vehcon.

- ► End-to-End (E2E) Testing was conducted in November 2019 through the end of December 2019. This testing stage began with customer service training, but primarily involved test drivers. The Test Team and HDOT participants, enrolled in the HiRUC TTD and used the system on a daily basis, culminating in participants receiving RURs. E2E testing was led by the Test Team, and involved both Azuga and Vehcon.

- ► The Small-Scale Operational Trial (SSOT) began in January 2020 and concluded with the launch of the Technology Test Drive. This included approximately 10 volunteer participants who enrolled early and used the system in real-world conditions. SSOT testing was led by the Test Team, and involved both Azuga and Vehcon.

- ► The Fleet Pilot testing was conducted in April and May of 2021 and concluded with the launch of the Fleet Pilot in May 15.

Test Results

All stages of tests were successfully completed with the solution performing as designed and intended. Unit test data and results are available in the folder "Unit Testing." Integration Test data results are available in the folder "Integration Testing." End-to-End Test and SSOT data and results are included in the folder "End-to-End Testing." Issues identified during the E2E Testing in the file HiRUC Parking Lot_Issue Log. The testing team and the Azuga development team worked to ensure that all bugs were fixed prior to Operational Go-Live. Fleet Test results are available in the folder "Fleet Testing."

Definitions & Abbreviations

TERM/ABBREVIATION	DEFINITION/DESCRIPTION
API	Application Programming Interface
Automated Reporting (Part 2)	Distance reporting using some form of technology, including devices that interface with a vehicle's electronics, smartphone image capture, and native automaker telematics systems
Azuga	Service Provider for the Automated Demonstration also known as Part 2 and Technology Test Drive
Business Rule	A requirement related to the business behavior of the system. Note that the distinction between technical System Requirements and Business Rules can be fuzzy, so both are tested at the same time.
Datawarehouse	A relational database containing all data for the Part 1 RUC Demonstration.
Defect	An error which results in an unexpected result during testing
Defect Triage	A process where each defect identified is prioritized and categorized by its severity, frequency
Defect Tracking Tool	A formalized recording and tracking of defects, their impacts and the activities to resolve same
DIT	Honolulu City & County Department of Information Technology (DIT)
End-to-End Test (E2E)	A methodology used to test whether the flow of an application is performing as designed from start to finish. E2E includes User Acceptance Testing
Integration Test	A level of testing where individual units are combined and tested as a group
JSON	JavaScript Object Notation (file format and data interchange format)
Manual Reporting (Part 1)	Distance reporting based on odometer readings collected during vehicle safety inspections
Mileage Reporting Method (MRM)	Drivers have a choice of plug-in device (with or without location) and Odometer Photo capture
OBD II	On Board Diagnostic II (vehicle diagnostic system)
OdoFoto	Mileage reporting method where user submits their odometer photo through a smartphone app
Part 1	The Manual Demonstration, in which Hawaii residents receive a Driving Report based on their odometer readings collected during safety inspections
Part 2	The Technology Test Drive, also known as the Automated Demonstration, in which ~2,000 volunteer participants receive Road Usage Reports over the 9-month test period based on a variety of Mileage Reporting Methods
Plug-in Device (PID)	A device that plugs into a vehicle's data port to record and report the vehicle's miles traveled.
Regression Testing	Testing comprised of re-running system tests to ensure that previously developed and tested software still performs as intended after a software or hardware change is made.
Requirement Traceability Matrix (RTM)	A document that links requirements throughout the testing and validation process

TERM/ABBREVIATION	DEFINITION/DESCRIPTION
Road Usage Charge (RUC)	A policy whereby motorists pay for use of the roadway network based on distance traveled
Road Usage Report (RUR)	Used in Part 2 only, this refers to the report a driver receives detailing the road usage charge.
Road Usage Report Generator (RURG)	Road Usage Report Generator, the component of the HiRUC system that creates Road Usage Reports based on travel data stored in the Datawarehouse.
Small-Scale Operational Trial (SSOT)	The Small-Scale Operational Trial is a soft launch of the system with HDOT employees as participants. The team made final adjustments before the Go Live with the general public. The team also used this period to deploy and test outreach materials.
System Requirement	A requirement related to technical performance of the system. Note that the distinction between technical System Requirements and Business Rules can be fuzzy, so both are tested at the same time.
Test Artifacts/Test Documentation	Collateral of testing which include requirements traceability matrix, test plans, test cases, test scripts, and any other items needed to design and perform a test
Test Cases	A subset of Test Scenario, defined as a set of actions executed to validate a particular feature or functionality of a system
Test Report	A document that gives a summary of all the tests conducted during testing
Test Data	All data and information which has been specifically identified for use in tests
Test Documentation	The complete suite of artifacts that describe test plans, test scripts and test results drawn from the testing activity
Test Environment	Consists of elements that support test execution with software, hardware and other configuration which mimic the real-world environment in order to uncover any environment/configuration related issues
Test Plan	Technical documentation which details the systematic approach to testing the system
Test Scenario	Any functionality that can be tested. A subset of Use Cases
Test Scripts	A line-by-line description of all the actions and data needed to perform a test
Test Strategy	A set of guidelines that explains the test process and determines how testing needs to be done
Test Tool	A product that supports one or more test activities right from planning, requirements, creating a build, test execution, defect logging and test analysis
Unit Test	A process in which the smallest testable parts of a system are individually and independently scrutinized for proper operation
Use Cases	A specific situation in which a product or service could potentially be used
User	A person who uses the manual or automated solution
UX	User Experience
Vendor	The organizations contracted to develop the system
VIN	Vehicle Identification Number

1. Introduction

1.1. Introduction

This document describes the testing carried out for HiRUC Part 2 of the Hawaii Road Usage Charging Demonstration, publicly called the Technology Test Drive, a nine-month demonstration of three mileage reporting methods:

► plug-in device with location, a device that plugs into vehicles data ports

► plug-in device without location, a device that plugs into vehicles' data ports but does not contain any location-determination technology

► Odofoto, a smartphone application for recording vehicle odometer

In the Technology Test Drive, participants select a Mileage Reporting Method, drive, receive monthly or quarterly invoices called Road Usage Reports, and provide feedback via online surveys.

For context, the HiRUC Demonstration project comprises two parts - Part 1 Manual and Part 2 Technology Test Drive. This document describes the activities performed to validate the functionality of the Part 2 Automated solution of the HiRUC Demonstration.

The HiRUC Part 2 System is specified in three documents:

► **HiRUC Part 2 System Requirements Specification (SRS)**, which contains the basic technical functionality (such as mileage reporting, account management, and security)

► **HiRUC Part 2 Interface Control Document,** which defines all system interfaces, including the interfaces related to the generation of RURs, the mileage message, and the JavaScript Object Notation (JSON) data reporting interfaces

► **HiRUC Part 2 Business Rules Document (BRD)**, which contains the business-oriented requirements for system performance

These are the documents that needed to be validated through testing.

1.2. Testing Approach and Phases

The approach to testing was to validate system functionality through different phases of testing and capturing participant feedback. Azuga maintained a **HiRUC Part 2 Requirements Traceability Matrix (RTM)** (filename *Azuga RUC Requirements Traceability Matrix HiRUC.xls*) that listed all system requirements and business rules, focusing on how requirements that Azuga developed for Oregon (ODOT) map to the HiRUC requirements.

The Test Team, Milestone and Arup, provided independent oversight for all testing and reviewed all inputs and outputs from the testing phases.

Testing was conducted in several phases, following a typical systems engineering approach:

Unit Testing: testing at the software component level. Each component of the software was tested to verify that the detailed design for the unit has been correctly implemented.

Integration Testing: the functional testing designed to test that all interfaces function as expected.

End-to-End Testing (E2E), incorporating User Acceptance testing, tested scenarios that reflect business processes and customer journeys which mirror the end-state operation of the system.

A **Small-Scale Operational Trial (SSOT)** was a soft launch of the systems with HDOT employees and/or project members as participants, focusing on functionality and customer experience. The participants were free to select the mileage reporting methods of their choice and different account types. SSOT focused on the full functionality of the system and the customer experience. The project team made final adjustments before the Go Live with the general public.

1.3. Test Planning and Documentation

The phases of testing were planned and specified in the following documents:

► **HiRUC Test Strategy**, the overall approach to testing

► **HiRUC Unit Test Scripts**, now incorporated into various Unit Test Results documents, as described in the section on Unit Testing below

► **HiRUC Part 2 Integration Test Plan**, which included plans for integration testing

► **HiRUC Part 2 End-To-End Test Plan**, which included plans for E2E and SSOT

Changes and updates to the plans were made while conducting this testing. Thus, this document supersedes those earlier documents in its record of the testing conducted.

1.4. Organization of this Document

The rest of this document is organized as follows:

► Section 2 provides a high-level overview of the HiRUC Part 2 system

► Section 3 describes the testing approach, including scope, purpose, conduct, environment, and exit criteria

► Section 4 describes Unit testing results

► Section 5 describes Integration testing and results

► Section 6 describes End-to-end testing and the Small-Scale Operational Trial and results

► Section 7 describes the Fleet Pilot testing and results

► Section 8 provides some overall testing recommendations and Lessons Learned

2. HiRUC System Overview

The Part 2 automated solution (as built by Azuga and Vehcon) is shown in Figure 1. This figure shows the solution and the interfaces between the components:

1. Mileage Collection Subsystem to the Account Management Subsystem - an internal interface used to exchange road usage data.

2. **Account Management Subsystem and the Datawarehouse Subsystem -** interface used to transfer account data updates, road usage data to generate RUR, and receive RUR status updates

3. **Account Management Subsystem and the RUR Generator Subsystem -** interface to allow RUR requests to be sent by Azuga for RURs to be generated and downloaded. Also includes RUR Generator sending RUR downloads links to Azuga.

4. **Account Management Subsystem and the HiRUC Administration -** Interface to transfer reports to HiRUC Administration, allowing for HiRUC system management, including an audit trail of mileage and (potential) revenue data.

Figure 1: Part 2 Solution
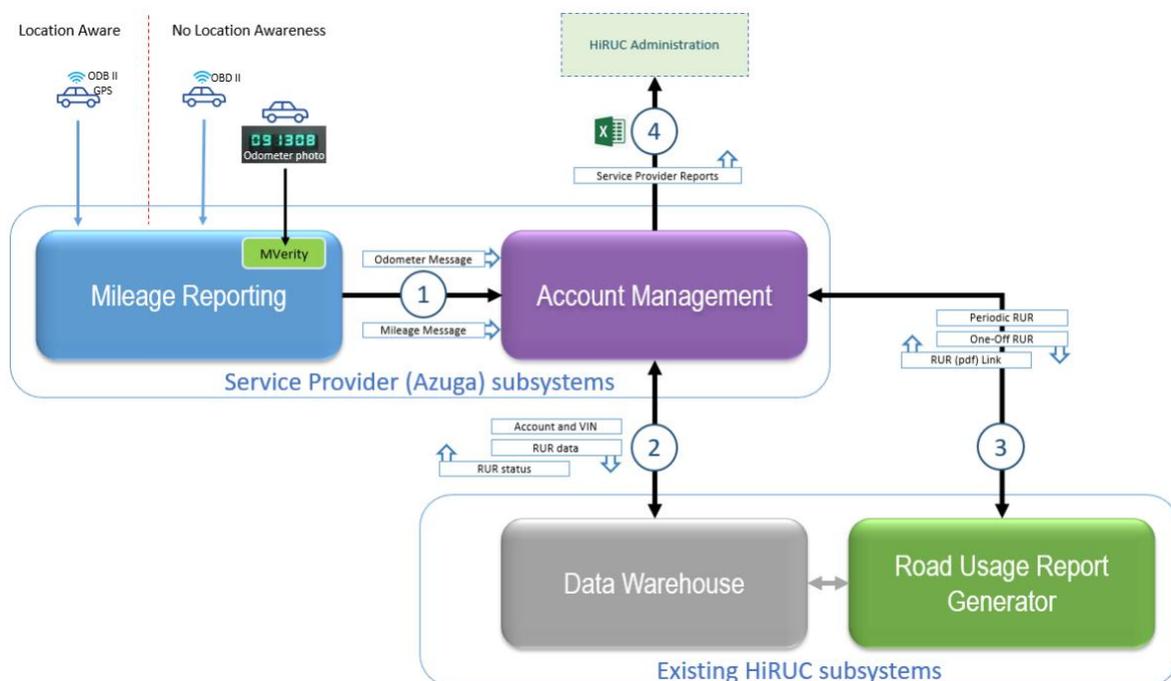
A more detailed overview of the system is provided in the HiRUC Automated Reporting Concept of Operations document.

3. Testing Approach

This section describes the approach to HiRUC Part 2 system testing, including the scope, purpose, conduct, environment, and entry/exit criteria.

3.1. Scope

3.1.1. In Scope

The scope of testing on the HiRUC project was to functionally test all Part 2 Requirements and Business Rules as they were developed and implemented in components and subsystems. Through the different phases, increasingly complete business processes (customer journeys) were tested.

The following elements are in-scope:

► Primary customer use cases
  > Enrollment
  > Plug-in Device installation
  > Mileage Capture
  > Account Closure
► Road Usage Report generation and distribution
► Feedback capture
► Data transfer security
► Small-Scale Operational Trial (SSOT)
► Carbon Footprint value-added service

3.1.2. Out of Scope

RURs are issued to participants for information purposes only. Thus, billing / payment mechanisms were not developed or tested.

The HiRUC mobile app has value-added services, called Premium Features, which are available to users but was not in scope for testing. The Carbon Footprint service was in scope because it was developed specifically for this project. The other value-added services were developed for previous projects by Azuga, and are not directly related to RUC. They were tested only in so much that the value-added services adhered to the requirements, any information displayed did not interfere with the demonstration.

3.1.3. Items Not Tested

Per contract, Azuga had the option to self-certify functionality of their overall solution has been implemented successfully elsewhere and were unchanged for HiRUC. The certification covered interfaces wholly within the Azuga solution. Such certification was subject to Milestone approval.

3.2. Purpose of Testing

The objectives of testing for HiRUC Part 2 were to ensure that:

► The system supports policy objectives for the HiRUC Demonstration

► Operating the Road Usage Report Generator in Part 2 does not cause unexpected system conflicts with the Driving Report Generator used for Part 1

► Participants would have an outstanding user experience

► Systems deployed performed as expected

► Participant data storage and manipulation was secure

► Interfaces between HiRUC Part 1 system and Part 2 system function as expected

► Interfaces between vendor systems function as expected

3.3. Conduct of Testing

► Unit and Integration Testing was conducted by Azuga, with support from Vehcon for Integration testing of interfaces involving Vehcon. Milestone and Arup provided review and feedback of Azuga's testing and results. E2E and SSOT were conducted by the Test Team and supported by Azuga.

Azuga and the Test Team conducted testing as described in the individual test plans. Additional tests were added as needed.

3.4. Testing Environment

Azuga and Vehcon conducted all tests using the HiRUC Part 2 System, which includes the following components:

► Azuga's RUC system, including

> A secure web portal, hosted in the cloud on Amazon Web Services (AWS).

> A backend transactions data processor and account management system, hosted in the cloud on AWS.

> Secure plug-in devices provided by Danlaw

> The HiRUC Azuga Insight mobile app, available for iOS and Android

► Vehcon's RUR Generator system was hosted on Amazon Web Services (AWS). This service incorporates various facilities to enable secure encrypted data (at rest and in transit) be processed and accessed:

- > EC2 is Amazon's Elastic Compute Cloud which allows the project to increase the computing power as required.

- > Amazon RDS for PostgreSQL is Amazon's Relational Database Service which is a web service that makes it easier to set up, operate, and scale a relational database in the AWS Cloud.

- > AWS Identity and Access Management (IAM) enables the user to manage access to AWS services and resources securely.

3.5. Entry and Exit Criteria

3.5.1. Unit Testing

► **Entry Criteria**: Completion of unit software development by Azuga, including any informal testing of the given software component.

► **Exit Criteria**: Unit tests completed and expected result achieved, test defects documented, triaged, and closed.

3.5.2. Integration Testing

► **Entry Criteria:** Completion of software interface development by Vehcon and Azuga, including any informal testing of the given software interface. Unit re-testing completed for items identified as required for Integration testing.

► **Exit Criteria:** Integration tests completed and expected results achieved, test defects documented, triaged, and closed.

3.5.3. End-to-End Testing

► **Entry Criteria:** Completion of unit testing and integration testing for all major components, PIDs available, Azuga Insight Customer Service operational. Unit and Integration re-testing completed for items identified as required for E2E testing.

► **Exit Criteria:** End-to-end test plans executed, and all required data gathered, test defects documented, triaged, and closed.

3.5.4. Small-Scale Operational Trial

► **Entry Criteria:** All high-priority issues identified during end-to-end testing fixed and confirmed through retesting (middle and low-priority issues can be resolved during SSOT). PIDs available via final distribution channel. Mobile apps available via Apple App Store and Google Play. Surveys developed for SSOT. Re-testing completed for items identified as required for SSOT testing.

► **Exit Criteria:** SSOT executed, all required data gathered, test defects documented, triaged, and closed; operations and customer service issues resolved.

4. Unit Testing

Azuga conducted a series of Unit Tests of the elements of their overall solution to ensure that each individual element worked as designed as customized for HiRUC and function expected. Completion of this step ensured that Integration and E2E Testing could be carried out efficiently.

Azuga performed testing of their solution to verify compliance with the System Requirements and Business Rules laid out for HiRUC.

Azuga's Unit Tests covered:

► The enrollment process (for all MRM types);

► Installation of mobile apps;

► Account management/changes across web, iOS and Android platforms such as change password, edit account details, etc.;

► Account closure; and

► Other elements.

► Azuga's unit testing consisted of:

> self-certification (validation of HiRUC requirements as already demonstrated for ODOT requirements) and

> internal software module level testing conducted by developers and QA engineers for all components developed newly for HiRUC.

4.1. Azuga Self-certification

Azuga originally developed a Requirements Traceability Matrix that mapped the OreGO requirements to the HiRUC requirements: Azuga RUC Requirements Traceability Matrix HiRUC.

Based on this RTM, Azuga self-certified a range of solution features identical to and deemed proven in deployment in OReGO. Azuga expanded on the RTM to create the following primary self-certification documents:

► *Azuga RUC-HiRUC-Self Certification-SRS-v2.1.docx.* This document includes all self-certification of the Systems Requirements Specification for HiRUC Part 2.

► *Azuga RUC-HiRUC-Self Certification-BRD-v2.1.docx.* This document includes all self-certification of the Business Requirements Document for HiRUC Part 2.

Further, Azuga maintained additional Requirements Traceability Matrices (RTMs) for self-certified requirements from their OreGO deployment, validating that the Oregon developments were accurate and complete:

► *Azuga Verification Cross Reference Index.xlsx*, the original Azuga RTM from 2015, indicating that all OreGO requirements were implemented and tested

► *NewTech Azuga CertEval FINAL.pdf*, an update of the original RTM requirements updates in November 2018

► *Azuga RUC Basic Device Self Certification Results v1.2.docx*, full documentation of the certification testing of the Basic Device in Oregon.

4.2. Unit Testing Results

► The above self-certification covered all requirements that were carried over from OreGO. However, HiRUC contained a range of new requirements and business rules not present in OreGO.

For all HiRUC requirements and business rules not covered by self-certification tests, Azuga performed new unit tests on the software. These Unit Testing results are presented in a spreadsheet format with information exported from Jira, an issue tracking product. The spreadsheet contains all Unit Tests completed; these tests can be filtered by:

► **Issue type**: a descriptor for each item - task, sub-task, story, bug, etc.

► **Key**: a unique identifier for each item.

► **Summary**: a brief description of the item.

► **Status**: item status, which can have the values open, in-progress, or closed.

► **Resolution**: item resolution—either unresolved or done.

► **Created**: the date when the item was created.

► **Project**: HiRUC

► **Description**: More detail regarding the item.

The Unit Testing results (beyond the self-certified requirements that Azuga had already developed for the ODOT system) are contained in the following files:

► *HiRUC Unit Test Issues Results.xlsx,* the primary table of software development unit testing — the development needed to convert the ODOT system to support the HiRUC requirements. Each issue has a key (e.g., HiRUC-1) that maps to a more detailed description of the issue and how it was tested in *Azuga-JIRA HiRUC Closed-Done-InQA 12232019.docsx*.

► Azuga-JIRA HiRUC Closed-Done-InQA 12232019.docx, detailed software development.

► *HiRUC - Azuga Web Portal Test Functionality Documentation.xlsx,* demonstration of complete HiRUC web portal functionality after all software updates from unit testing was completed.

5. Integration Testing

Following the successful completion of Unit Testing, the Vendor began Integration Testing[1]. This involved testing across four interfaces as illustrated in Figure 1 above. Each of these interfaces was tested until it worked as specified and expected.

5.1. High-level Description of Integration Tests

A series of tests were carried out by the vendors, Azuga and Vehcon. These included testing of the following four interfaces:

► **Testing Interface 1** - **Mileage Collection Subsystem to the Account Management Subsystem**, is entirely contained within the Azuga System. The test focused on the receipt of correct road usage data which would be used in order to generate RURs across Interface 2. This was achieved by Azuga creating multiple test accounts which were assigned with differing MRMs. The data flowed from the mileage reporting subsystem 'across' interface 1 into the Account Management Subsystem and then across interface 2 into the Master Datawarehouse.

► **Testing Interface 2** - **Account Management Subsystem to the Datawarehouse Subsystem**, is the primary interface tested between Azuga's Account Management Subsystem and the HiRUC Master Database Subsystem. To test this, Azuga established a set of test data in order to create and amend test accounts created on their Account Management System. This test data was then used to communicate, bi-directionally, with the existing HiRUC Master Datawarehouse to verify that the account changes had occurred and been reflected in the Master Database as expected.

► **Testing Interface 3 - the Account Management Subsystem to the RUR Generator Subsystem**, tested the data flow between the two. This test was used to verify whether the Master Datawarehouse (periodically or requested/one-off) could send an RUR / RUR status update correctly.

► **Testing Interface 4** - **Account Management Subsystem to the HiRUC Administration**, is the dashboard of information for the project team. Development and testing of this interface were completed in June 2020.

5.2. Integration Test Results

► Integration test results for test activity between Azuga and Vehcon were documented in *HiRUC Integration Test Results v1.1.docx*.That document contains the results of integration testing between the Azuga RUC platform (Account Management system) and HiRUC subsystems external to the Azuga platform. These include the HiRUC Datawarehouse, the HiRUC RURG, and the Vehcon Mverity system.

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[1] Reference Document: Automatic Demonstration Integration Test Plan v0.4.docx

► The results include the messages and corresponding responses between the systems listed in support of enrolling participants and their vehicles in the overall HiRUC system, processing odometer readings, and producing Road Usage Reports (RURs). The key messages include the Account and VIN Update message, the RUR Data Report, the RUR Request, and the MVerity application programming interface (API) calls and responses for processing odometer images captured through the Azuga Insight App.

► Scenarios covered include new enrollments as well as account updates and closures for device and OdoFoto account types. RUR Data Report and RUR Request exchanges were documented as well as an OdoFoto rejection example.

6. End-to-End Testing and Small-Scale Operational Trial

The purpose of E2E testing was to exercise the entire HiRUC solution from end to end, from driver enrollment to account closure and everything in between. The findings from the test were fed back into the Vendor's development team to fix bugs, improve the user experience, and to ensure that the final HiRUC TTD solution satisfies the requirements.

Milestone invited a few 'friendly' testers/participants, consisting of HDOT employees, sub-consultants and limited members of the public, to participate in E2E testing.

The first step of this phase was to design and draft test scripts for each tester. These scripts ensured that testers knew what they needed to test without requiring intimate knowledge of the project and that the Test Team could ensure that they had covered the breadth of the solution to ensure all aspects were verified. In addition to the Test Scripts, a HiRUC E2E Participant Matrix was created. This matrix allowed the Test Team to quickly and easily trace the participants, their test details and current stage of testing.

In total, there were over 30 test accounts created, across each county and inclusive of different account types[2], vehicle types[3] and mileage reporting methods[4].

► Testers outside of the Team Test followed the instructions contained within their Test Script

► The Test Team created multiple accounts per person to test specific scenarios or scenarios which required a deeper understanding of the system design/requirements.

> For example, the Test Team drove significant mileage on private roads to test whether the GPS PID could successfully differentiate between private and public roads and apply the correct RUC rate.

E2E Testing ran from December 9, 2019 to December 20, 2019.

► Participants received their Test Scripts via email the weekend prior.

► Several Participant[5] accounts were then closed at the end of E2E testing.

However, the issuance of Road Usage Reports was delayed until December 31 for most participants due to minor development issues, which were fixed. Further RUR issues, including RURs for participants who changed their mileage reporting methods, were resolved later during SSOT.

An issues list was created for and maintained throughout the course of E2E Testing to track bugs and other issues as they arose, and to identify mitigating actions and issue status updates. This

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[2] Personal and Fleet
[3] Type 1: Gas & Diesel. Type 2: Battery Electric and Plug-in Hybrid.
[4] OdoFoto, Plug-in Device with and without GPS. Changing MRM was also tested.
[5] Some testers wanted to continue testing the system and devices. Other accounts were also left open for re-testing.

testing tool was crucial to clearly capturing and communicating bugs to the Vendor's development team. The issues list was documented in *HiRUC Parking Lot_Issues Log.*

The issues captured in the issues list were categorized and were checked against the exit criteria for E2E Testing to ensure that no significant issues were carried over to SSOT or Production.

6.1. E2E Results and Documentation

E2E testing results consisted of:

► *E2E Participant Matrix,* which contains both the list of participants and is a record of the results/outcomes of each step of the testing

► *Test Scripts*, instructions for the participants

► *Issues List,* a list of the issues discovered during testing and a record of how and when they were fixed

6.1.1. E2E Participant Matrix

The E2E Participant Matrix is a spreadsheet which contained information on all E2E Test participants, including the steps and status of their testing, relating directly to the steps detailed in their Test Script. This detail allowed the Test Team to track all participants and their progress throughout E2E Testing.

The participant matrix also served as the primary record of results from E2E testing. Each step of testing recorded in a separate column, and the Test Team filled in the experiences at each step in those rows S through BG. If the step is completed without issue, the Test Team filled the box with an X. If there is an issue, the issue was described and filled in, and also added to the Issues list if it is a newly discovered issue (repeat/redundant issues are not added to the issues list). Reference: *HiRUC_E2EParticipantMatrix V04.xlsx*

6.1.2. Test Scripts

To ensure that each E2E Test participant's testing scenario was clear and that the participants tested what the Test Team required, a common Test Script was developed. These Test Scripts varied depending on the MRM given to the participant, providing the specific steps associated with the particular MRM. The script included detail on the MRM, test activities and detailed steps for the participants to follow. Test Team members tested many various other scripted and unscripted scenarios such as unplugging the PID, changing MRM, and changing / adding vehicles.

6.1.3. Issues List

The issues list served as the record of decisions for issues identified during E2E testing. The Issues List is a spreadsheet that was maintained throughout the project. Issues recorded prior to E2E were recorded in a tab called 'General List'. Starting in E2E testing, all issues discovered were recorded in the 'E2E Issues List', which contains issues pertaining to the E2E Testing. Issues discovered during SSOT were also recorded in the E2E issues list.

The spreadsheet contains a complete list of issues discovered during testing with a unique number, a description of the issue, the person who found it, the date discovered, the issue owner, a

mitigation action, issue priority, a due date and notes. Reference: *HiRUC Parking Lot_Issues Tracker.xlsx*

6.2. Small-Scale Operational Trial

The Small-Scale Operational Trial (SSOT) was launched in January 2020. This phase of testing included the participation of approximately 30 participants (most of whom were located in Hawaii) and further tested the HiRUC Part 2 solution, in a more developed, near-production like environment.

Results of the SSOT were captured in the issues list dated January 1, 2020, onward.

The purpose of the Small-Scale Operational Trial was to operate the TTD with a small group of volunteer participants from the project team and HDOT so that they can experience HiRUC as a citizen would in the full pilot. The SSOT participants utilized the range of mileage reporting methods with the objective to iron out any usability issues, so that Azuga could finalize the operational processes and verify the systems, in a near-final-state of operation. Any issues that arose were addressed and lessons learned applied prior to roll out to the public.

Participants in SSOT went through the following steps, with the project team seeking feedback continuously on their experiences and progress:

► Invitation
  > Mailchimp invite sent by Milestone
► Enrollment
  > Linking from invite to the Azuga Website
  > Signing up to the Azuga Website
  > Adding vehicle(s)
  > Selecting a mileage reporting option
    • Odometer reading (OdoFoto)
    • OBDII with GPS or
    • ODBII with no GPS
► Delivery and fitting of OBDII device (does not apply to OdoFoto)
► Downloading and signing-on to Azuga Mobile App
► Initial odometer photo (for OdoFoto accounts only)
► Capture of mileage by driving on variety of roads (public and private) across counties of Hawaii
  > Take second photo of their odometer (OdoFoto)
  > OBDII device captures and transmits mileage data
    • With location if GPS device utilized
► Engagement with Customer Services as necessary

► Receive Road Usage Reports (RURs)

► Change mileage reporting method

> From PID to OdoFoto

> From OdoFoto PID

At the end of each RUR cycle, the project team analyzed the RUR data reported, and reconciled the data both with the data displayed on RURs and with data displayed on the customer portal. This full circle of test allowed to check that data consistency throughout for participants. All RUR test defects were corrected.

7. Fleet Pilot Testing

As a part of the HiRUC demonstration project, a fleet pilot study was developed. This pilot study recruits fleet operators across the four Hawaii counties: City & County of Honolulu, Hawaii County, Kauai County and Maui County. They are provided with a prototypical billings system developed by a software vendor (Azuga) that:

► Stores (records) and displays in-fleet vehicles information, along with editing capabilities

► Decodes vehicle identification number (VIN) to the United States Environmental Protection Agency (EPA) fuel efficiency (in miles per gallon)

► Collects an initial and final odometer readings associated with the recorded vehicles during a demonstration period of a month (noting that in an operational RUC program, the RUC collection period could be a quarter or another longer period of time)

► Generates automated statements for a road user charge and a fuel tax paid[6] for all recorded vehicles in the fleet

For this manual RUC system, two options are provided to the fleet operator to record the vehicle and odometer information – individual upload (user types in each data field needed for each vehicle) and bulk upload (user uploads a spreadsheet/CSV file of data containing each vehicle).

This section summarizes the UAT and SSOT results conducted over the month of May 2021, and includes discussions of the three phases of testing: "Initial UAT" (conducted while Azuga was still finishing the software), "Pre-Launch UAT" (conducted after Azuga finished, but before the production server was provisioned) and "Pre-Launch SSOT" (conducted on the production server, including fixes for issues discovered in the previous phases). These testing phases led up to the launch date of the RUC software was May 26, 2021. UAT system refers to a software system that is not available to any user, only the developer and test team and using a login account. SSOT system refers to a software system that is available to selected/permitted users with login accounts, and the developer and test team. After a "launch", the SSOT system is made available to all users with login accounts. While the developer has editing capabilities with the user interface, the user or test team do not have this ability – the software is available in a "read only" mode. User has only one login account, while a developer or test team can have multiple login accounts.

The UAT and SSOT have two broad goals, to conduct user interface checks and to conduct software functionality tests. These goals and questions formed the basis for the testing structure, and are described in this section.

The data used in the tests and screenshots collected were archived. This report summarizes the key test results and conclusions just prior to the launch of the software system.

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[6] Fuel tax paid may not be collected from a vehicle upon shifting to a road user charge. It is computed as miles traveled by vehicle divided by vehicle fuel efficiency (in miles per gallon, the EPA's City-Highway Fuel Economy rating for the given vehicle) times fuel tax rate (in dollars per gallon), which varies by county.

7.1. User Interface Checks

This section documents the user interface checks performed for UAT (in "Initial" stage) and SSOT ("Pre-Launch" stage) systems. Table 1 summarizes the status of the 10 user interface checks conducted.

Table 1: User Interface Checks Conducted

#	QUESTION TESTED	PASSED
1	Does the User Guide ("how to") match and support the user with the HiRUC Fleet Pilot?	Y
2	Are there frequently asked questions (FAQ) and information on ("what is") HiRUC and HiRUC Fleet Pilot?	Y
3	Does the user know what the RUC and fuel tax rates are in each county in Hawaii?	Y
4	Is it easy to enroll and create an account?	Y
5	Are login / password for the registered account working smoothly?	Y
6	Are the screens or tabs for the account after login logical, working and easy to use?	Y
7	Is the information on each screen or tab for the account intuitive and understandable?	Y
8	Are uncommon terms/words defined or footnoted?	Y
9	Is the account accessible on mobile devices?	Y
10	Is help and troubleshooting support easily accessible and ready for launch?	Y

Detailed results of the checks are presented below.

1. Does the User Guide ("how to") match and support the user with the HiRUC Fleet Pilot?

The user guide provides essential instructions to fleet operators for setting up and using account to enroll fleet vehicles and report mileage at vehicle enrollment time (referred as "vehicle upload"). The user guide also provides instructions to report mileage in the middle and at the end of the HiRUC Fleet Pilot (referred as "odometer upload"). The different ways to add vehicles, namely, individual upload and bulk upload are explained. The required data fields, data format in case of bulk upload, example data entries and common precautions (e.g., VIN should have exactly 17 characters, the pilot system does not support kahakōs and 'okinas) are mentioned. The user guide also provides information on the statements that will be automatically generated and indicates clearly that this is simulated and no funds are owed by fleet operators. Lastly, the user guide provides details on the customer support for the software platform and frequently asked questions (FAQs) on HiRUC and the HiRUC Fleet Pilot.

2. Are there frequently asked questions (FAQ) and information on ("what is") HiRUC and HiRUC Fleet Pilot?

Figure 2 shows FAQs that are included in the HiRUC Fleet Pilot user guide.

Figure 2: Screenshot of HiRUC and HiRUC Fleet Pilot and FAQs

Frequently Asked Questions

What is the HiRUC Fleet Road Usage Charge Pilot

The HiRUC Fleet Road Usage Charge Pilot is a continuation of the HiRUC Technology Test Drive project except that it is specifically designed for fleet operators. The main purpose of both pilots is to evaluate alternative funding methods for road and bridge maintenance as the traditional fuel tax continues to decline as a viable funding source. The reason for the decline in fuel tax revenues is continued improvements in vehicle fuel efficiency, and the advent of hybrid and electric vehicles which are expected to increase. This pilot is designed to evaluate the unique needs of fleet operations in support of a potential road usage charge program.

When does the HiRUC Fleet Road Usage Charge Pilot start and end?

The pilot starts on May 24, 2021 and ends on June 30, 2021. However, you will have some extra time in July to access your final statement.

What is RUC?

RUC is simply short for "road usage charge."

How much does it cost to participate in the HiRUC Fleet Road Usage Charge Pilot?

Participation is free and all road usage charges are simulated. So participants do not pay anything during the pilot. You are simply helping Hawaii study road and bridge maintenance funding alternatives from the perspective of a fleet operator.

3. Does the user know what the RUC and fuel tax rates are in each county in Hawaii?

These are included in the FAQ section of the user guide. Tables 2 and 3 show the RUC rates and fuel tax rates by county in Hawaii.

Table 2: RUC Rate by County

STATE/COUNTY	RUC RATE (PER MILE)
State	$0.008
Hawaii	$0.011
Honolulu	$0.008
Kauai	$0.008
Maui	$0.011

Table 3: Fuel Tax Rate by County

| STATE/COUNTY	FUEL TAX RATE (PER GALLON
State	$0.180
Hawaii	$0.230
Honolulu	$0.165
Kauai	$0.170
Maui	$0.230

4. Is it easy to enroll and create an account?

The account enrollment and creation follows standard and common practices. Basic instructions for creating an account are included in the HiRUC Fleet Pilot user guide. The user can use email or custom text as username. The account is secured using a password and security PIN and also requires confirmation through email.

5. Are login / password for the enrolled account working smoothly?

For all test accounts created for HiRUC Fleet Pilot, the login and password worked smoothly. Figure 3 shows a screenshot of the login screen where the user enters the enrolled username and password after an account is confirmed through email.

Figure 3: Screenshot of HiRUC Fleet Pilot Account Login Screen
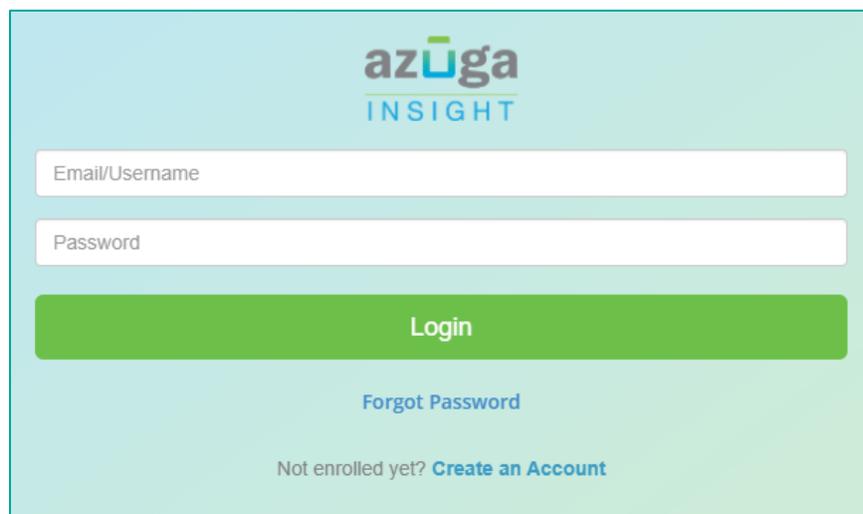
6. Are the screens or tabs for the account after login logical, working and easy to use?

Both the UAT and SSOT systems show the same screens upon login. They are logical and easy to use. "Vehicles" and "Account" screens or tabs are clickable from the start. "Dashboard" and "Statements" screens or tabs are not clickable at the start; however, after vehicle information was entered, these become clickable.

7. Is the information on each screen or tab for the account intuitive and understandable?

Figures 4 through 9 show sample screens for "Dashboard", "Statements", "Vehicles" and "Account" tabs of the HiRUC Fleet Pilot UAT or SSOT Systems. These are intuitive and understandable.
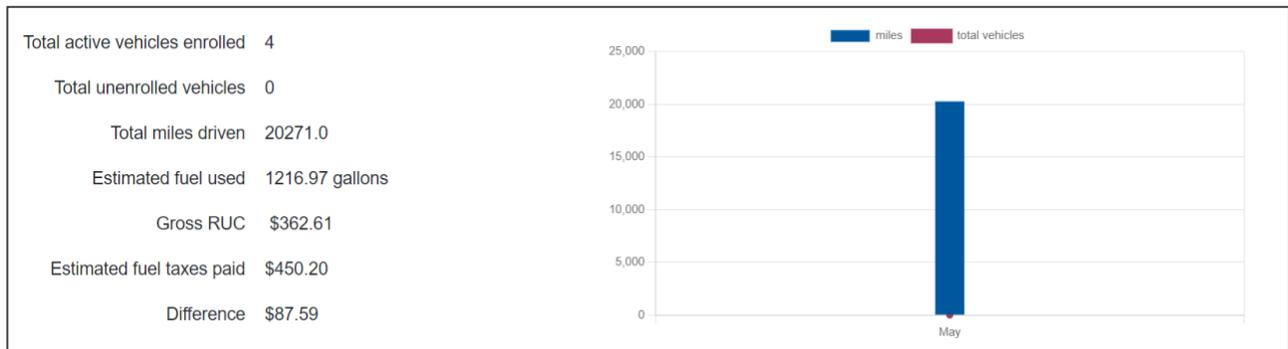
Figure 4: Sample "Dashboard" Screen

Total active vehicles enrolled	4
Total unenrolled vehicles	0
Total miles driven	20271.0
Estimated fuel used	1216.97 gallons
Gross RUC	$362.61
Estimated fuel taxes paid	$450.20
Difference	$87.59

Figure 5: Sample "Statements" Screen Before Statements are Generated

Date	Type	Size	View or Save
		Your Next Statement is expected on July 5.	

Figure 6: Sample "Statements" Screen After Statements are Generated

Date	Type	Size	View or Save
May 2021	Statement	-	📄 ⬇

Figure 7: Screenshot of "Vehicles" Screen Before Vehicles are Added

You need to add vehicles to your account. You can add vehicles by uploading CSV files or manually through this portal.

Click the button below to add vehicles.

Add Vehicles

Figure 8: Screenshot of "Vehicles" Screen After Vehicles are Added

Add Vehicle | Upload Odometer Data

Show 10 entries   Search:

Nickname	VIN	Year	Make	Model	EPA Combined MPG	License Plate	Initial Odometer	Date Added	Latest Odometer	Date Latest Odometer uploaded	Current Mileage	Status		
696	1FMPU14576LA83458	2006	Ford	Expedition	14	696	79649.0	05-26-2021	88000.0	05-26-2021	8351.0	ACTIVE	Edit	Remove
760	1FTEX1CFXFKF09064	2015	Ford	F-150	18	760	21685.0	05-26-2021	26090.0	05-26-2021	4405.0	ACTIVE	Edit	Remove
742	1FMCUDF79DUB16510	-	-	-	-	742	36097.0	05-26-2021	-	-	-	PROCESSING	Edit	Remove
681	1FAFP53266A262890	2006	Ford	Taurus	20	681	47485.0	05-26-2021	55000.0	05-26-2021	7515.0	ACTIVE	Edit	Remove

Showing 1 to 4 of 4 entries   Previous 1 Next

Figure 9: Screenshot of "Account" Screen

Account Admin Information

Email address   testing+fleet12@hiruc.org
First Name   TREVOR   Last Name   REED
Phone Number   2068193794
PIN   123

Company Information

Company   Eagle
Street Address 1   600 Wilshire Blvd #750
Street Address 2   null
City   Honolulu   Zip Code   96795

8. Are uncommon terms/words defined or footnoted?

File format for vehicle and odometer upload was mentioned as comma-separated values or "CSV" format as a footnote next to the associated upload screens.

A term "Flagged" is used in "Vehicles" screen for some of the vehicles that are added. This term is defined or explained as follows:

> *A flagged vehicle means that the VIN could not be decoded. Customer support will attempt to manually decode the VIN. If they cannot, they will reach out to you to obtain more information about the vehicle.*

The UAT and SSOT systems testing team did not find any other noteworthy definitions or footnotes on the display screens of a logged in account. However, the testing team noted that the HiRUC Fleet Pilot user guide provides additional definitions for terms such as "RUC" (road user charge), "VIN Decoder", etc.

9. Is the account accessible on mobile devices?

Yes, the account is accessible and works as expected on various mobile devices.

10. Is help and troubleshooting support easily accessible and ready for launch?

A "Contact Us" dialog box is available through the UAT and SSOT systems as shown in Figure 10. This was not working at the start of testing but was fixed in updates made by Azuga. The HiRUC Fleet Pilot user guide indicates: Azuga customer support is available from 08:00 AM to 5:00 PM HT. The phone and email forms for help and troubleshooting support are working as expected.

Figure 10: Screenshot of "Contact Us" Dialog Box
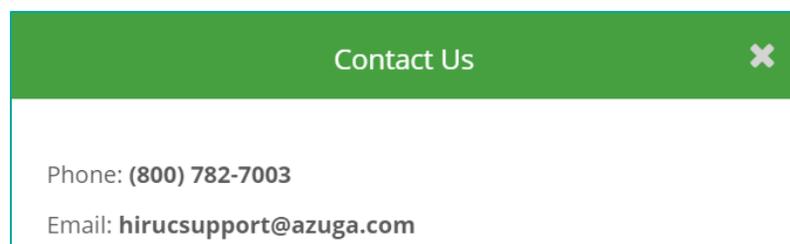
7.2. Software Functionality Tests

► This section provides a listing of accounts created to test software functionality and their test purpose. A summary of the test results when using UAT (in "Initial" and "Pre-Launch" stages) and SSOT ("Pre-Launch" stage) systems is also presented with the help of screenshots, when needed. In case an issue was found to repeat across multiple test accounts, results or screenshots for only one of the test accounts is included in this report. Detailed results, output screens and issues identified for all test accounts were archived.

7.2.1. Initial and Pre-Launch UAT testing

Test Accounts Created

► A "John Paul" Account (user experience and Initial UAT) plus Accounts 1-10 (Initial UAT accounts), plus Account 12 (Pre-Launch UAT account) were created. Table 4 shows the descriptions and purposes of UAT accounts.

► The UAT accounts generally use real VINs, a few intentional errors were introduced to the VINs for testing purposes. Intentional errors are described below under Testing Purpose. The VINs used in testing were primarily collected from the following website: https://hawaiicars.com/.Additional websites were also used for heavy vehicles including: https://www.commercialtrucktrader.com, https://www.freightlinerofhawaii.com, and other truck sales websites.

► For the UAT, in total 2,256 VINs were collected by the testing team. Of these, 2,188 vehicles are non-electric light vehicles, 56 are electric light vehicles, and the remaining 12 are heavy vehicles. The test accounts 1, 3 through 10 and 12 have non-overlapping VINs. "John Paul"

Account had some overlap with the remaining UAT accounts; in these cases, the VINs were not uploaded as they were already on Azuga's UAT system.

► For the UAT account number 2, 739 VINs were tested; the test failed due to a "hang" issue with the bulk vehicle upload file (the bulk upload simply hung, failing to complete). So, the VINs were re-used in other UAT tests. Azuga confirmed a performance issue in uploading more than 250-300 vehicle or odometer values from a file and the "hang" issue will be handled through a future software update(s).

► 1,825 of the 2,256 VINs were used by the end of Pre-Launch UAT. Most testing was done in the initial UAT. Items were re-tested in Pre-launch UAT, after the initially identified issues were fixed.

Table 4: UAT Test Accounts

TEST DATE	ACCOUNT NUMBER	ACCOUNT DESCRIPTION	TEST TYPE	TEST PURPOSE
May 12, 2021	John Paul	150 VINS all unique, Nickname were the same "A", No License Plate # entered, some odometer readings were negative, some unrealistically large, Hawaii County for all.	Initial UAT	Multiple 1. No License Plate # 2. Negative and unrealistically large odometer readings
May 12, 2021	John Paul	150 VINS all unique, Year 2021, Nickname different for all, No License Plate # entered, Oahu entered as County for all instead of Honolulu.	Initial UAT	Multiple 1. No License Plate # 2. Negative and unrealistically large odometer readings 3. Mistyped county information
May 12, 2021	John Paul	150 VINS for 2020 vehicles, Nickname unique for all, Unique License Plate # entered, Maui County for all.	Initial UAT	VIN less than 17 characters
May 12, 2021	John Paul	150 VINS for 2021 vehicles, 10 HV VINs added in the mix, Nickname unique for all, Unique License Plate # entered, Oahu used as County for some and Honolulu for others.	Initial UAT	Mistyped county information
May 14, 2021	1	40 VINs, Bulk EVs - All Counties	Initial UAT	Vehicle Upload for EVs
May 17, 2021	2	739 VINs, Bulk Mix of HVs and LVs & All Counties	Initial UAT	Due to a "System Hang Issue", no tests could be performed using this account.
May 17, 2021	3	186 VINs, Bulk Non-EV LVs – Maui	Initial UAT	Vehicle Upload for Fleet in Maui County
May 18, 2021	4	185 VINs, Bulk Non-EV LVs – Honolulu	Initial UAT	Vehicle Upload for Fleet in Honolulu County
May 19, 2021	5	37 VINs, Bulk Mix of HVs and LVs & All Counties	Initial UAT	Multiple: 1. Vehicle Upload for Multi-County Fleet 2. Incorrect or Missing or Repeating VIN, Nickname or License Plate 3. Incorrect or Missing County of Registration 4. Kahakō and 'Okina letters in Nickname or License Plate or County of Registration
May 18, 2021	6	114 VINs, Bulk Non-EV LVs – Kauai	Initial UAT	Vehicle Upload for Fleet in Kauai County

TEST DATE	ACCOUNT NUMBER	ACCOUNT DESCRIPTION	TEST TYPE	TEST PURPOSE
May 19, 2021	7	25 VINs, Bulk Non-EV LVs – Hawaii	Initial UAT	Vehicle Upload for Fleet in Hawaii County
May 20, 2021	8	25 VINs, Bulk Non-EV LVs - Hawaii - No Final Odometer Reading or Missing VINs in Odometer Upload	Initial UAT	Vehicle Upload for Fleet without Final Odometer Reading or with missing VINs in Odometer Upload
May 19, 2021	9	18 VINs, Bulk Any Type of Vehicle - Number of Characters in Nickname = 25	Initial UAT	Vehicle Upload for Fleet with Nicknames = 25 Characters Long (Test Data in Hawaii County)
May 19, 2021	10	160 VINs, Bulk Non-EV LVs - Kauai and Maui - Different Mix of Odometer Readings	Initial UAT	Vehicle Upload for Fleet with Missing or Impossible Initial Odometer Readings (including Negative or Large Initial Odometer Values)
May 26, 2021	12	47 VINs, Bulk and Individual, All Counties, All Vehicle Types	Pre-Launch UAT	To test all issues identified in Initial UAT

Key Test Results and Issues Identified

► To test the system, scenarios were developed, the appropriate data and files were created and uploaded or entered into the system, and the results observed. The key results of the UAT and comparisons between the Initial and Pre-Launch UAT are summarized in the Table 5.

Table 5: Key Test Software Functionality Results

#	QUESTION TESTED	PASSED
1	Are both individual and bulk upload options working?	Y
2	Is the upload taking place in a reasonable amount of time (expecting less than a minute under an approximately 100 Mbps internet speed)?	Y
3	Are there example upload files or guidance for the format of input data?	Y
4	While uploading, are common (a reasonable set of) anticipated error situations handled correctly and communicated clearly?	Y
5	Is the upload failure reason making sense and does it help user identify the correction needed?	Y
6	Are the RUC and fuel tax credit calculated correctly?	Y
7	Are the statements accurate, clear and consistent with the online account?	Y

Detailed results are provided below:

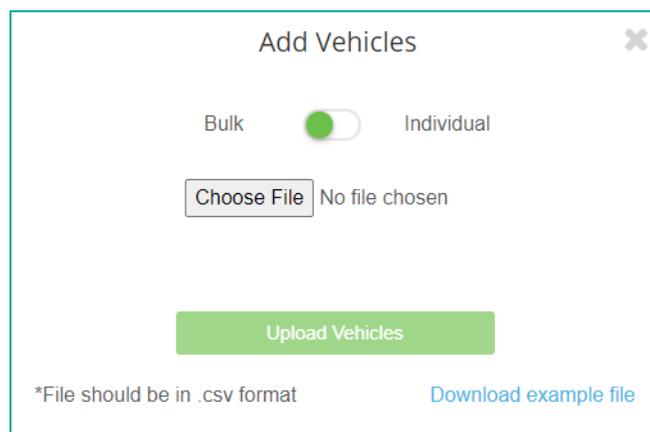**1. Are both individual and bulk upload options working?**

2. Is the upload taking place in a reasonable amount of time (expecting less than a minute under an approximately 100 Mbps internet speed)?

Both individual and bulk upload options were worked well for small fleet sizes (up to 180 vehicles). A system hang occurred with very large fleet sizes (over 700 vehicles). The largest fleet size that was uploaded successfully both in terms of vehicle/initial odometer reading and final odometer reading in the UAT is: 186 vehicles.

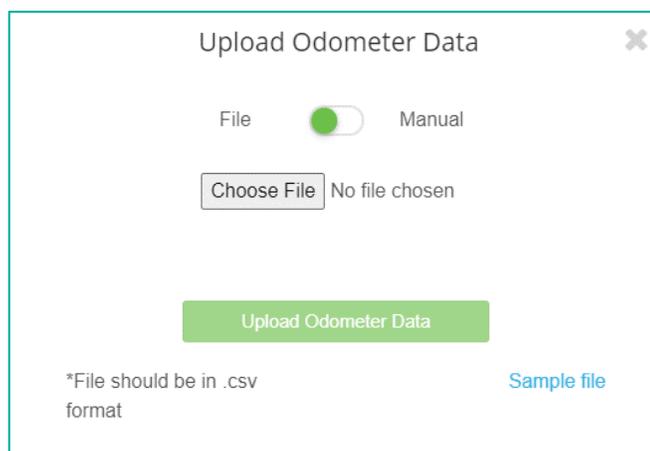**3. Are there example upload files or guidance for the format of input data?**

Example vehicle and odometer files were provided for bulk upload option as shown in Figures 11 and 12.

Figure 11: Download Example File Link for Bulk Vehicle Upload

Figure 12: Download Example File Link for Bulk Odometer Upload

For individual upload option too, there is text to guide the user, as shown in Figure 13.

Figure 13: Individual Vehicle Upload

4. While uploading, are common (a reasonable set of) anticipated error situations handled correctly and communicated clearly?

Azuga's software reports vehicle upload failure in an online / hypertext markup language (HTML) tabular format (illustrated in Figure 14) as well as downloadable PDFs.

Figure 14: Vehicle Upload Failure Example Report

Failed Vehicles List

This is a list of all the vehicles that failed and reasons the vehicle failed. Data for each vehicle that failed must be fixed prior to attempting to upload those vehicles again in order to ensure the vehicles are uploaded successfully

Nickname	VIN	Failure Reason
TANGO87	WA1LXAF78LD002492	WA1LXAF78LD002492 already exists on the account
TANGO75	KM8K53A52LU541064	KM8K53A52LU541064 already exists on the account
TANGO81	KNDJ23AU7L7026334	KNDJ23AU7L7026334 already exists on the account
TANGO66	JM1NDAM70L0418246	JM1NDAM70L0418246 already exists on the account
TANGO63	JA4AR3AU6LU030768	JA4AR3AU6LU030768 already exists on the account

OK

Copy List to Clipboard | Print List

5. Is the upload failure reason making sense and does it help user identify the correction needed?

Common anticipated error situations with vehicle upload were tested and evaluated for correctness in error handling and clarity in communications as shown in Table 6. The Initial UAT found that the vehicle upload failure reasons were not always making sense, these were fixed in the updates made by Azuga in the Pre-Launch UAT stage. A few issues remain unresolved even at the Pre-Launch UAT stage. These are: (1) The count of vehicles goes up after deleting and re-adding vehicle; re-added vehicle treated as a new vehicle. (2) There is no error handling for a very large or unrealistic odometer reading, which can be a result of a typographical error by the user. Incorrect odometer data entry can lead to incorrect RUC statement / invoice.

Table 6: Vehicle Upload - Initial UAT and Pre-Launch UAT Test Results

VEHICLE UPLOAD TEST / ISSUE	INITIAL UAT RESULT	PRE-LAUNCH UAT RESULT	PASSED
Missing VIN	VIN must be exactly 17 characters.	Mandatory fields are missing. Please provide all the mandatory fields	Y
Less than 17 characters	VIN must be exactly 17 characters.	VIN values must be exactly 17 characters.	Y
More than 17 characters	VIN must be exactly 17 characters.	VIN values must be exactly 17 characters.	Y
Missing County of Registration	Mandatory fields are missing. Please provide all the mandatory fields.	Mandatory fields are missing. Please provide all the mandatory fields	Y
Odometer Reading containing commas in double quotes	Not tested	The odometer value for 3FA6P0HR0DR193013 is invalid. It must be a positive number.	Y
Missing Nickname	Mandatory fields are missing. Please provide all the mandatory fields	Mandatory fields are missing. Please provide all the mandatory fields	Y

VEHICLE UPLOAD TEST / ISSUE	INITIAL UAT RESULT	PRE-LAUNCH UAT RESULT	PASSED
More than 25 Characters Nickname	Nickname is limited to 25 characters.	Truncated to 25 characters	Y
One character	Nickname must be unique.	Allowed	Y
Non-unique Nickname	Nickname must be unique.	Allowed	Y
Mistype County of Registration	The county of registration provided is invalid.	The county of registration provided is invalid.	Y
Odometer Reading containing commas but not within quotes	Error message reads as: N/A	Allowed	Y
Delete and re-add vehicle; Check count on dashboard	Count goes up after deleting and re-adding vehicle; re-added vehicle treated as a new vehicle.	Count goes up after deleting and re-adding vehicle; re-added vehicle treated as a new vehicle. While deleting, asking for last odometer reading.	Fixed 5/27/21
Missing License Plate	License plate must be unique.	Mandatory fields are missing. Please provide all the mandatory fields	Y
More than 7 characters	License plate is limited to 7 characters.	License plate is limited to 7 characters.	Y
Less than 7 characters	License plate is limited to 7 characters.	Allowed	Y
Non-unique License Plate	License plate must be unique.	License plate must be unique.	Y
Use of 'Okina in County of Registration	CSV does not recognize 'Okina, converts to a ? The county of registration provided is invalid.	CSV does not recognize 'Okina, converts to a ? The county of registration provided is invalid.	Waived
Odometer Reading containing commas in single quotes	Not tested	The odometer value must be a positive number.	Y
Missing Odometer Reading	Error message reads as: N/A	Mandatory fields are missing. Please provide all the mandatory fields	Y
Negative Odometer Reading	The odometer value must be a positive number.	The odometer value must be a positive number.	Y
Text as Odometer Reading	Error message reads as: N/A	The odometer value must be a positive number.	Y
Very Large Odometer Reading; Also, Latest Odometer Reading less than Initial Odometer Reading.	No handling of this error or reasonable checks. Expecting a change of status from active to processing.	No handling of this error or reasonableness checks.	Fixed 5/27/21
Use of Kahakō in Nickname	CSV does not recognize Kahakō, converts to a ?	CSV does not recognize Kahakō, converts to a ?	Waived
Electric Vehicle (EV) - 2014 Tesla Model S	No upload issue; however, Fuel Tax Credit computed	No upload issue; zero Fuel Tax Credit computed	Y
Heavy-Duty Vehicle (HV) - 2019 Freightliner	Allowed, and often missing US EPA's Miles per Gallon (MPG)	Vehicle Gross weight is more than 15000 pounds not allowed to upload	Y
Medium-Duty Vehicle (MV) - 2005 Ford F650	Allowed, and often missing US EPA's Miles per Gallon (MPG)	Vehicle Gross weight is more than 15000 pounds not allowed to upload	Y

Odometer upload failure is reported in an online / hypertext markup language (HTML) tabular format (illustrated in Figure 15**)** as well as available in downloadable PDFs.

Figure 15: Odometer Upload Failure Example Report

Some Odometer Readings Failed to Upload

This is a list of all the rows that failed and reasons the odometer upload failed. Data for each vehicle's odometer value that failed must be fixed prior to attempting to upload those odometer values again in order to ensure the values are uploaded successfully

Nickname	VIN	Failure Reason
n/a	1FMSK7DH8MGB45131	The VIN does not belong to testing+fleet4@hiruc.org
BRAVO10	1FTBF2A62MEC71012	Odometer cannot be updated for flagged vehicle.

OK

Copy List to Clipboard | Print List

Common anticipated error situations with odometer upload were tested and evaluated for correctness in error handling and clarity in communications as shown in Table 7. The main issue found in the Initial UAT stage is on odometer reasonableness checking. There is no error handling for a very large or unrealistic odometer reading. Also, when the mileage in the odometer upload file is missing or lower than the mileage included in the vehicle upload file, the UAT system assumes the final odometer is the same as the initial odometer, and computes zero RUC. The user is not notified on the lack of consistency between odometer readings in the vehicle upload and odometer upload files. More information should be collected from the user on the VINs that have unrealistic or missing final odometer readings or showing non-positive change between vehicle upload (initial odometer reading) and odometer upload (final odometer reading).

Table 7: Odometer Upload - Initial UAT and Pre-Launch UAT Test Results

ODOMETER UPLOAD TEST	INITIAL UAT RESULT	INITIAL PRE-LAUNCH UAT RESULT	PASSED
Missing VIN	No test result; the error message of VIN already in the account superseded this test.	Latest Odometer assumed as same as Initial Odometer for missing VIN.	Fixed 5/27/21
More than 17 characters	Since vehicle upload for such a vehicle with VIN more than 17 characters will fail, the error message for odometer upload indicates the vehicle is not in the account.	Since vehicle upload for such a vehicle with VIN more than 17 characters will fail, the error message for odometer upload indicates the vehicle is not in the account.	Y
Missing Odometer Reading	No test result; the error message of VIN already in the account superseded this test.	Odometer reading missing error message is generated. Latest Odometer assumed as same as Initial Odometer.	Fixed 5/27/21
Negative Odometer Reading	No test result; the error message of VIN already in the account superseded this test.	Invalid odometer value (must be a positive integer value). Assumes the latest odometer to be the same as the initial odometer.	Fixed 5/27/21
Final Odometer Reading less than Initial Odometer Reading	Odometer should be greater than previous odometer reading. Assumes the latest odometer to be the same as the initial odometer.	Odometer should be greater than previous odometer reading. Assumes the latest odometer to be the same as the initial odometer.	Fixed 5/27/21

ODOMETER UPLOAD TEST	INITIAL UAT RESULT	INITIAL PRE-LAUNCH UAT RESULT	PASSED
Very Large Odometer Reading	No handling of this error or reasonableness checks.	No handling of this error or reasonableness checks.	Fixed 5/27/21
Electric Vehicle (EV) - 2014 Tesla Model S	No upload issue; however, Fuel Tax Credit computed for electric vehicle.	No upload issue; zero Fuel Tax Credit computed for electric vehicle.	Y

6. Are the RUC and fuel tax credit calculated correctly?

Based on a comparison of dashboard and calculated miles driven, fuel used, RUC and fuel tax, the testing team found differences in Maui and Honolulu Counties and only in terms of RUC and fuel tax in the Initial UAT stage. Azuga confirmed that there was an error in the RUC and fuel tax rates for Maui and Honolulu counties. These were fixed in updates made by Azuga and re-checked by the test team.

7. Are the statements accurate, clear and consistent with the online account?

The statements generated by Azuga were confirmed to be accurate, clear and consistent with the online account for all counties.

Figure 16: Initial UAT Dashboard Reported versus Calculated Metrics, Maui County

Total number of vehicles enrolled	167
Total miles driven	137780.0
Total Fuel used	6075.85 gallons
Gross RUC	$2204.49
Fuel Tax Credit	-$1974.63
Net RUC	$229.86

7.2.2. Pre-Launch SSOT

The purpose of the pre-launch SSOT was to validate changes on the actual production system. Table 8 provides descriptions and purposes of SSOT accounts.

For the SSOT account number 15, 638 and 504 VINs collected during the Initial UAT were tested; both tests failed due to an upload system hang. So, the VINs were re-used in the Pre-Launch UAT. Azuga confirmed a performance issue in uploading more than 250-300 vehicle or odometer values from a file and the system hang for large files will be handled through a future software update(s).

For the SSOT account number 16, Hawaii DOT provided to the testing team five (5) additional VINs with real locations in Hawaii. Four of these were tested for bulk upload and one of them was tested for individual upload.

Table 8: SSOT Accounts and Their Purpose

TEST DATE	ACCOUNT NUMBER	ACCOUNT DESCRIPTION	TEST TYPE	TEST PURPOSE
May 24, 2021	15	634 and 504 VINs, Bulk and Individual, All Counties, All Vehicle Types	Pre-Launch SSOT Site	Test large size fleet vehicle and odometer upload on SSOT system
May 26, 2021	16	5 VINs, Bulk and Individual, All Counties, Real Vehicle Locations	SSOT Site	Test VINs provided by Hawaii DOT on SSOT system

The key results of SSOT are as follows:

► Both individual and bulk upload options worked well and the upload time was very short (a few seconds).

► Similar to the UAT system, the SSOT system provided example bulk vehicle and odometer upload files. The SSOT system too had suggestive text for individual vehicle upload.

► While performing the bulk vehicle upload, the SSOT failed to upload one vehicle (nickname = 653) which included a non-allowed VIN character among I, O, Q or special character. The error message is correct and communicated clearly. The result is shown in Figure 17.

Figure 17: SSOT Bulk Upload Failed Vehicles List

► One of the vehicles (nickname = 742) was uploaded but "flagged" as missing US EPA MPG and status is set to processing as shown in Figure 18. This also made sense.

Figure 18: SSOT Account 16 Bulk Upload Succeeded Vehicles Result

Nickname	VIN	Year	Make	Model	EPA Combined MPG	License Plate	Initial Odometer	Date Added	Latest Odometer	Date Latest Odometer uploaded	Current Mileage	Status	
696	1FMPU14576LA83458	2006	Ford	Expedition	14	696	79649	05-26-2021	79649	05-26-2021	0	ACTIVE	Edit Remove
760	1FTEX1CFXFKF09064	2015	Ford	F-150	18	760	21685	05-26-2021	21685	05-26-2021	0	ACTIVE	Edit Remove
742	FLAGGED	-	-	-	-	742	36097	05-26-2021	0	-	0	PROCESSING	Edit Remove
681	1FAFP53266A262890	2006	Ford	Taurus	20	681	47485	05-26-2021	47485	05-26-2021	0	ACTIVE	Edit Remove

Flagged vehicle means that the VIN could not be decoded. Customer support will attempt to manually decode the VIN. If they cannot, they will reach out to you to obtain more information about the vehicle

► The single vehicle individual upload and odometer upload were also performed successfully using the information provided by Hawaii DOT.

► RUC and fuel tax provided on the "Dashboard" screen (see Figure 19) were verified to be correct, and the statement generated was found to be accurate, clear and consistent with the "Dashboard" (see Figure 20).

Figure 19: SSOT Account 16 Dashboard

Total active vehicles enrolled	4
Total unenrolled vehicles	0
Total miles driven	20271.0
Estimated fuel used	1216.97 gallons
Gross RUC	$362.61
Estimated fuel taxes paid	$450.20
Difference	$87.59

Figure 20: SSOT Account 16 Statement

This is a simulated statement. No actual funds are being used

Your May bill is   -$87.5

Road Usage	$362.61
Estimated fuel taxes	$450.20
Difference :	-$87.59

No issues were identified based on the SSOT except the system hang issue with large fleet upload.

7.2.3. Remaining Issues List and Launch

The following outstanding issues were identified by the testing team and were fixed by Azuga through software updates and re-tested by the Test Team:

► When vehicles are deleted and re-added, the deleted vehicle is still being counted towards the total count of vehicles on the dashboard (fixed).

► Reasonableness checks on uploaded mileage were added

► Improved notification for missing / negative odometer

    a. When the second odometer upload has a missing or negative odometer, the user gets an error, and the initial odometer is used as the default value. This amounts to a zero change in mileage or a zero RUC, which is correct. However, on the vehicle form display, no further message is given to indicate that the odometer is missing. Ideally, such a message would be given. It is noted that for the purposes of this pilot, vehicles will be considered to be compliant so long as any second odometer value is given.

    b. If a line in an upload file does not contain a VIN, but does contain an odometer value, no error is given. Ideally, all lines would either be completely blank, contain useful values and some form of user notification.

► The Contact Us button on the SSOT server not working was resolved by Azuga on May 28, 2021 (Friday).

Based on the UAT and SSOT results, the testing team made the decision on May 26, 2021 (Wednesday) to launch the HiRUC Fleet Pilot.

8. Testing Lessons Learned and Recommendations

Following E2E and SSOT Testing the following observations and recommendation were made:

► Distinguishing between public/private/off-road can be difficult without a 'golden map', a digital map that contains all the correct designation of road type (public/private/off) for all roads. This was not achievable during E2E Testing with the current mapping applications. Preliminary research by the project team revealed that not all counties in Hawaii make a database of public vs. private roads available. The ability to distinguish between public and non-public roads is one of the main reasons for providing a GPS-enabled device to lessen the impact of RUC. Azuga updated the algorithms used for the TTD to the best available API for the HiRUC TTD. Research into the ability to distinguish public vs. non-public travel continues.

► The advertisement of value-added services to participants is challenging. For many participants, there is high interest in value added services and gamification. However, as these value-added services are not core to RUC, some participants in prior RUC pilots expressed a preference for value-added services to be opt-in only. The result of requiring opt-in for the value-added services is that the value-added services inadvertently became more hidden and less used. They required another step to toggle on, were less obvious within the app and website, and so many participants were never aware of and never enabled them. This meant that many participants did not get the full experience of the expected production version of the Azuga Insight mobile app and their feedback was limited to the basic RUC experience. As a result of this finding, per request, Azuga added an email notification about Premium Features two weeks after enrollment if the participant has yet to enable premium features. The email resulted in a modest increase in enablement.

► E2E testing highlighted the importance of having project team members on the ground in Hawaii during early stage testing. The testing benefited from having Test Team members as well as a representative from the Vendor present during at least part of the E2E testing. This physical presence afforded the Test Team the opportunity to test and query elements of the Vendor's solution and receive immediate response and action. With any globally distributed project group, there is value in bringing the different representatives of the project together for Testing to ensure cohesion and speed of response. Time differences would otherwise render the fix resolution process too onerous and time-consuming.

► The use of the necessary sandbox environments (AppHost) for both Apple iOS and Android apps—by which users can download the apps before they are available in the respective app stores—was confusing and cumbersome for Test participants and distracted from feedback on the core enrollment process. Participants expressed some frustration which was reflected in the feedback. For future pilots, a more clearly documented process and better communication may mitigate this when the mobile app to be tested is not yet publicly available. When possible, apps should be available in the App Store and Google Play.

► When a previously developed customer-facing solution, (be it a website or mobile app), is being reused for a new project, the customization of the system for the new project must be detailed

and thorough, and the completed system should be thoroughly reviewed by the project team. Conducting a solution walkthrough and requirements clarification kick-off helped the team get synched up quickly. Azuga's detailed RTM produced for the kick-off, which linked the HiRUC requirements to the ODOT requirements from the project for which Azuga developed the system, facilitated discussions around the amount of customization that was needed for the project. It is inevitable that elements of the design for the prior pilot slip through and additional customization be needed. The more time is available for thorough testing, the better.

► Because one of the most important aspects of mileage reporting is distance accuracy, distance accuracy testing must occur early in testing. Testing should be conducted locally, with the device hardware, firmware and software that will be deployed. As PIDs were not originally designed for RUC, RUC specific requirements should be developed to ensure that the level of accuracy meets RUC needs.

► Error handling is needed for all interfaces between systems developed by different organizations. Even if an interface is working correctly, the interface may change in unexpected ways that can lead to a failure such as a timeout that leads to the interface not working.

> Specifically, it is important to have a system in place to monitor the reminders sent by SMS text message for the OdoFoto methods. The monitoring system ensures participants receive timely notifications and reminders that helps them comply with the mileage reporting cycle. A monitoring system allows the systems operator to be proactive and re-send missed notifications for participants to be reminded in time to submit their readings before the reporting deadline. In the absence of such a monitoring system, the pilot or program runs the risk of low compliance from Odofoto participants.

► RUC statement format and layout are vital elements of pilot projects. Creating good statements is resource intensive. Especially when the statement serves as an outreach tool for exploring a new concept with users, creating good statements requires great system flexibility. Statement design should therefore be part of system requirements and specifications so the system provider can plan for the necessary system adjustments to deliver the desired statement design. The risk of leaving the statement design to the end, i.e. after the entire RUC system has been designed, is that statement design could be relegated to a technical or functional deliverable instead of being considered as a key communication artifact.

► Hawaii has many private roads and special addresses. Azuga typically delivers plug-in devices through package delivery services. However, for these special addresses, Azuga had to handle deliveries differently, through use of the U.S. postal service.

► Developing software for the exploding number of web and mobile platforms (phones, tablets, browsers, etc.) is extremely challenging and time consuming. It requires both development and test teams to have many test tools to ensure that most users have a smooth experience. As a safety net, communications and responsive, well-trained customer service are key to handle the exceptions and legacy systems.

► Any change in hardware merits thorough retesting. Azuga began the project with a relatively new hardware variant of their plug in device, with a new 4G cellular modem, needed because 3G systems are becoming unavailable in many states. While this device had been thoroughly tested by the manufacturer, and further tested by Azuga, it was found during SSOT that some miles went missing, which was discovered to be due to a change in the firmware caused by the switch to the 4G cellular modem. This issue was resolved through a firmware upgrade but illustrates the need for very thorough regression testing when hardware is updated.

► Fleet operators need a method to not only do bulk uploads but to work with individual vehicles. Confirmation of upload success and/or errors for both methods and individual vehicle status needs to be clear to ensure that operators can ensure compliance without needing to call Customer Service to get additional details.