



Demonstration Phase 1: Driving Report Test Report

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ARUP



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Appendix A Testing

Executive Summary

This document describes the testing carried out for of Part 1 of the Hawaii Road Usage Charging Demonstration.

The objectives of testing for HiRUC were to ensure that:

- ▶ registered vehicle owners would have an outstanding User Experience from the moment they receive the Driving Report in the mail to the moment they respond to the online survey on the HiRUC website. This would allow HDOT to garner useful feedback from the registered vehicle owners and use this to inform their future decisions and policy-making.
- ▶ systems deployed performed as expected, in a secure manner, ensuring secure manipulation and storage of registered owner data.

Testing Stages

Testing was carried out in four phases Unit, Integration, End-to-End and a Small-Scale Operational Trial (SSOT). Included in these tests were a number of Non-Functional tests carried out to ensure the solution could meet the requirements of performance and data/cyber security. Each stage of testing is captured within this document with the methodology, results and findings reported and discussed.

The system areas under testing included the Data Import, Data Cleaning and Driving Report Generation. In Unit testing, test ('dummy') data was utilized, while in the later stages, actual data sampled from DIT and PMVI sources were used during testing. SSOT used real participants and so their actual data was used during that stage.

The Part 1 solution was designed as follows:

- ▶ Data is gathered and validated through inputs from the DIT and PMVI
- ▶ This data is then 'cleaned' through the elimination of erroneous data fields and incomplete records
- ▶ Eligible records are identified through the application of Business Rules (BR)
- ▶ A Driving Report file containing eligible records is generated and communicated to the Print House (Cardinal)
- ▶ Driving Reports are printed and mailed to the user by the Print House

In order for the system vendor (Vehcon) to successfully complete Part 1 testing, each Business Rule and System Requirement was tested and a successful outcome achieved. Each test was captured and reported via a Requirements Traceability Matrix (RTM), to allow for full traceability of testing each requirement.

Testing Timeline

- ▶ Unit Testing was completed in June 2019 following the completion of the Data Warehouse and Driving Report Generator.
- ▶ Integration Testing was completed in July 2019, this included testing on the interface points of the system, namely, the loading of data from the DIT and PMVI into the Data Warehouse.
- ▶ End-to-End Testing was conducted in September through to the end of October, in conjunction with the Small Scale Operational Trial. Integration Testing with the Print House (Cardinal) was conducted at this stage. End-to-end testing and the Small Scale Operational trial saw the generation, printing, manual review and posting of 44 Driving Reports.

Test Results

All tests were successfully completed with the solution design performing as designed and expected. During E2E/SSOT, a number of lessons were learned. These lessons resulted in several minor changes to the process and the DR itself.

The full extent of the testing and results are contained within the rest of the document and its appendices.

Definitions & Abbreviations

TERM/ABBREVIATION	DEFINITION/DESCRIPTION
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 know as Part 2 and Technology Test Drive
Datwarehouse	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, etc.
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)
Driving Report (DR)	Used in Part 1 only - this refers to the report a driver receives detailing the road usage charge.
Driving Report Generator (DRG)	Module designed to use the data imported from PMVI and DIT databases, apply Business Rules to determine whether a Driving Report is to be produced for the period for each eligible vehicle, and generate data for the Driving Report if so qualified.
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.
National Change of Address (NCOA)	A secure dataset of approximately 160 million permanent change-of-address (COA) records consisting of the names and addresses of individuals, families and businesses who have filed a change-of-address with the USPS
Integration Test	A level of testing where individual units are combined and tested as a group
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 GPS) and Odometer Photo capture.
OBD II	On Board Diagnostic II (vehicle diagnostic system).
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 participants receive Road Usage Reports over the 9-month test period based on a variety of Mileage Reporting Methods.
Requirement Traceability Matrix (RTM)	A document that links requirements throughout the testing and validation process
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.



TERM/ABBREVIATION	DEFINITION/DESCRIPTION
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.
Test Artifacts	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 Design	A process that describes “how” testing should be done
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. Can be seen as 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 test design 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 is a report on the testing of the HiRUC Part 1 System for generating Driving Reports. Driving Reports are two-page descriptions of a driver's road usage based on data obtained from PMVI vehicle inspections. These Reports are being mailed to the owners of over 500,000 vehicles in Hawaii during the Part 1 Demonstration.

For context, the HiRUC Demonstration project comprises two distinct parts - Part 1, the distribution of Driving Reports, and Part 2, the Technology Test Drive. These two parts test potential options for implementing Road Usage Charging. This document outlines the various activities performed to validate the functionality of the Part 1 System.

The HiRUC Part 1 System is specified in two documents:

- ▶ **HiRUC System Requirements Specification (SRS)**, which contains the basic technical functionality (such as data storage, data import, security), and
- ▶ **HiRUC Business Rules Document (BRD)**, which contains the specific rules for generating the Driving Reports

These are the two documents that needed to be validated through testing. Ultimately, the line between requirements and business rules is somewhat fuzzy, as they both specify the manner in which the system should behave. For this reason, the requirements and business rules, as contained in the SRS and BRD, were tested together.

1.2. Phases of Testing

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

- ▶ **Unit Testing:** testing at the software component, in isolation from other components. Each unit (basic component) of the software was tested to verify that the detailed design for each unit has been correctly implemented, but without functional external interfaces. Thus, unit testing was executed using self-developed “dummy” data.
- ▶ **Integration Testing:** testing that the software interface, function as expected using real data.
- ▶ **End-to-End Testing (E2E):** Testing the system from end-to-end using real data—starting with real data, generating Driving Reports.
- ▶ **Small Scale Operational Trial (SSOT):** transmitting system-generated Driving Reports to a small number of volunteers. SSOT tested both functionality and customer experience. The Project Team then made final adjustments before the Go Live with the general public based on feedback obtained from SSOT. E2E testing and SSOT were conducted together—using data for the volunteers, the Driving Reports were generated (the E2E testing) and then mailed to volunteers and their feedback gathered (the SSOT).

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 Outline**, which contained plans for unit testing
- ▶ **HiRUC Part 1 Integration Test Plan**, which included plans for integration testing
- ▶ **HiRUC Part 1 End-To-End Test Plan**, which included plans for E2E and SSOT

These plans were generally followed, but 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.

Throughout all phases of testing, the team maintained a **HiRUC Part 1 Requirements Traceability Matrix (RTM)** that lists all system requirements and business rules, and specifies the phase at which the feature was tested.

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 system.
- ▶ Section 3 describes the testing approach, including scope, purpose, conduct, environment, and exit criteria.
- ▶ Section 4 describes Unit testing and 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 provides some overall recommendations and Lessons Learned.
- ▶ Appendix A with details on all stages of testing.

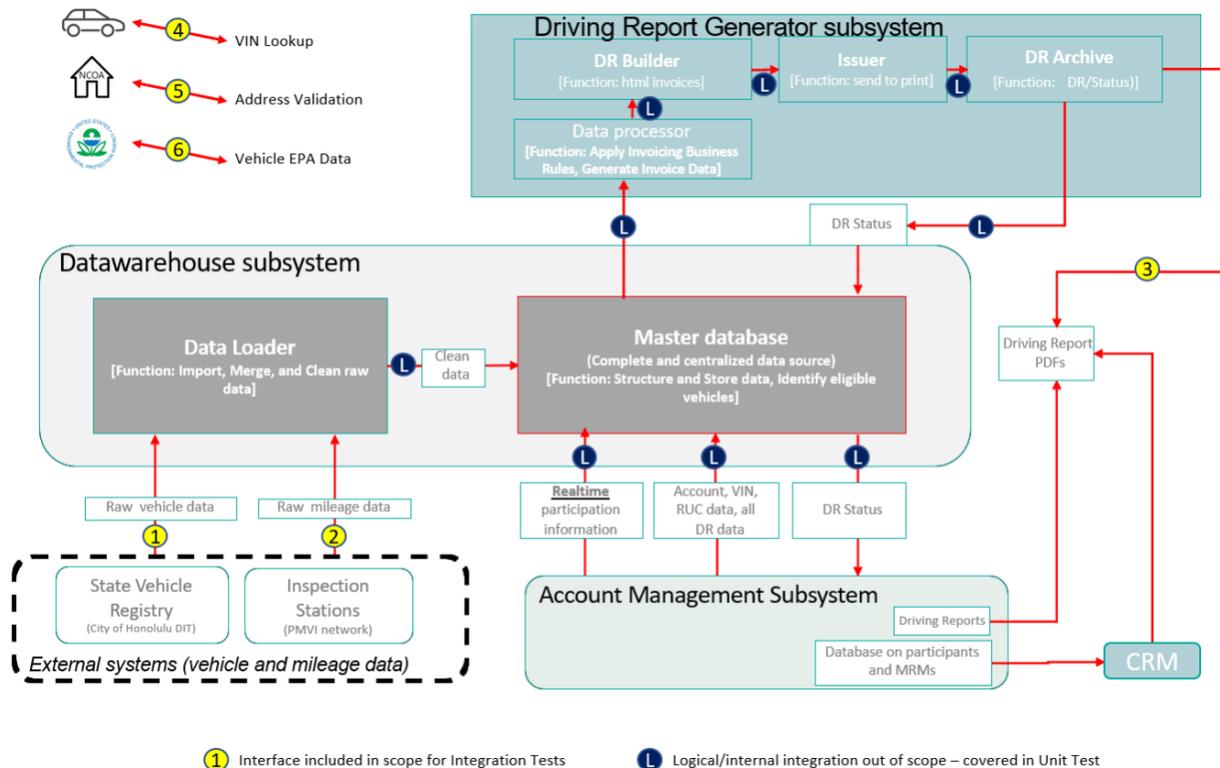
2. HiRUC System Overview

The HiRUC Demonstration is being conducted in two parts. This document describes the testing of the System developed for Part 1 of the testing.

Part 1 is a solution in which vehicle owners receive a Driving Report based on their odometer readings taken at their periodic motor vehicle inspection (PMVI). Business rules defined which drivers and vehicles were eligible to receive a Driving Report. The primary data collection was via the existing databases of the PMVI and the state vehicle registry, maintained by Honolulu City & County Department of Information Technology (DIT). The Part 1 solution was built by Vehcon.

Figure 1 illustrates the HiRUC Part 1 System, highlighting six system interfaces:

Figure 1: Part 1 Solution with Interfaces (Numbered 1 – 6)



Further detail of the HiRUC system, including a full description of this figure, are provided in the Concept of Operations document.

3. Testing Approach

This section describes the approach to HiRUC Part 1 system testing, including the scope, purpose, conduct, environment, and exit criteria.

3.1. Scope

The scope of testing on the HiRUC project was to functionally test all 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.

3.1.1. In-Scope

- ▶ Data Load of PMVI and DIT data
 - > Data Cleanse of imported data & Loading of cleansed data to Data Warehouse
- ▶ Generation of Driving Reports
 - > VIN Lookup / Address Validation (NCOA) / Vehicle EPA Lookup
 - > Printing of Driving Reports / Posting to users
- ▶ Capture of feedback from test participants (SSOT)

3.1.2. Out of Scope

- ▶ The Driving Reports are mailed to vehicle owners for information only, with no billing or payment required from the vehicle owners. Thus Account Management and Payment mechanisms were not developed or tested.
- ▶ Performance testing (that is, speed of processing) was not explicitly performed. However, it was determined that speed is non-critical—the system could compute more than 40,000 Driving Reports per day, easily enough to provide the Driving Reports each month.
- ▶ Analytics on DIT and PMVI data, beyond what was done to ensure that the Data was clean.

3.2. Purpose of Testing

The objectives of testing for HiRUC were to ensure that:

- ▶ registered vehicle owners would have an outstanding User Experience from the moment they receive the Driving Report in the mail to the moment they respond to the online survey on the HiRUC website. This allows HDOT to garner useful feedback from the registered vehicle owners and use this to inform their future decisions and policy-making.
- ▶ systems deployed performed as expected, in a secure manner, ensuring secure manipulation and storage of registered owner data.

3.3. Conduct of Testing

- ▶ Testing was conducted by Vehcon. Milestone and Arup provided review and feedback of Vehcon's testing and results.

Vehcon conducted testing generally as described in the individual test plans. However, at the time of testing, Vehcon made updates to plans as needed. As Vehcon validated requirements were validated, they recorded those in the RTM.

3.4. Testing Environment

Vehcon conducted all tests using the HiRUC Part 1 System, which includes the following components:

- ▶ The data sources of DIT and PMVI was provided on secure FTP servers hosted by Honolulu City & County and Parsons respectively. Access to the data was secured by login credentials and even then, only from authorized computers using IP whitelists. File downloads were performed using FileZilla.
- ▶ The HiRUC 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. Testing Exit Criteria

The following criteria were required for successful completion of SSOT and transition to pilot launch.

- ▶ Data files sent to the Printing house are consistent, complete and respecting Business Rules and System Requirements
 - > No duplicate vehicles and duplicate owner/address combination
 - > Only eligible vehicles, according to Business Rules, provided Driving Reports
 - > Mileage values and number of months between odometer readings are within defined range
 - > Miles per gallon values are decoded consistently
 - > Correct per-mile and gas-tax rates are used per vehicle registration address
 - > Potential road usage charges and estimated gas tax paid are correctly rounded
 - > Correct vehicle types are identified (electric vehicle, fleet vehicle, non-electric/standard internal combustion engine vehicle)
- ▶ Driving Reports have correct layout for all user types
 - > Electric vehicles Driving Reports data are printed to the correct preprinted Driving Reports shells (non-comparison)
 - > Non-electric/standard internal combustion engine vehicle powered vehicles Driving Reports data are printed to the correct preprinted Driving Report shells (comparison)



- > Each Driving Report data field is correctly printed in the expected placement on the preprinted Driving Report shell.
- > QR codes are correctly printed on Driving Report
- ▶ Driving Reports print out, folds, and mailed within specifications
- ▶ Recipients understand the Driving Report, are guided to the online survey, and are able to successfully complete the online survey
 - > Collect and incorporate feedback from SSOT participants to improve the Driving Reports

As indicated below, all these criteria were achieved following E2E/SSOT at the start of November 2019. The pilot then launched.

4. Unit Testing (June 2019)

Unit Testing involved testing at the software component, in isolation from other components. Each unit (basic component) of the software was tested to verify that the detailed design for each unit has been correctly implemented, but without functional external interfaces. Thus, unit testing was executed using self-developed “dummy” data using the same data elements as the “real” data, but constructed specifically to enable testing of the applicable Business Rules. 19 records of such self-constructed data were developed.

Unit Testing involved testing internal two system modules:

- ▶ Datawarehouse, including data storage and data cleansing
- ▶ Driving Report Generator, including computing the values to be used on each Driving Report
- ▶ See Appendix A.1 for greater details of Unit Testing

4.1. Datawarehouse Including Data Cleansing

A Datawarehouse, including a Data Loader and Master Database (see Figure 1 above) was developed specifically for use in Part 1. The Datawarehouse securely stores all data necessary to generate Driving Reports.

Vehcon ran a number of tests and analysis on the data they received from both the DIT and PMVI within the Datawarehouse. This analysis was fundamental to shaping the overall solution. It allowed HiRUC Team to fine-tune the Business Rules and System Requirements developed for the solution. It also ensured that only eligible users would receive DRs, and that the information contained within the DRs would be correct and received by the correct user.

4.2. Driving Report Data File Generation

The Driving Report Generator (DRG) module was designed to use the cleaned and merged data imported monthly from PMVI and DIT databases. The DRG applied a number of Business Rules to this data in order to determine whether a Driving Report was to be produced for the period for each eligible vehicle.

For Unit Testing, a data set was constructed so that the Business Rules related to Driving Report Generation could be tested in isolation.

As indicated above, the test data set contained 19 records. These 19 records were passed through the DRG. The DRG correctly identified the exclusions based on Business Rules. Twelve of the 19 records were correctly deemed ineligible for the generation of a Driving Report. The remaining 7 records were correctly deemed as qualifying for a Driving Report.

This same test data set was then passed through the DRG a second time. The second pass correctly identified that the 7 records, identified as qualifying during the first pass, had already been used to generate a Driving Report and were now ineligible to receive another. This was an important Business



Rule which ensured that any vehicle would only receive a single Driving Report during the HiRUC Demonstration, as intended.

5. Integration Testing (July 2019)

Integration Testing, performed in July 2019, involved uploading real Data from the PMVI and DIT databases into the HiRUC system. See Appendix A.2 for details of Integration testing.

5.1. Description of Data

5.1.1. DIT Data

The DIT data contains the registered owner's details for each vehicle in Hawaii. DIT provided a complete data set (monthly during operation) to the vendor, which was loaded into the Datawarehouse. The Integration Tests required the solution to ingest the data provided by the DIT and applying a series of Business Rules to correctly interpret and store the imported data in the Datawarehouse in a consistent format which could be later used to generate a Driving Report.

5.1.2. PMVI Data

The PMVI data contains vehicle inspection data including the odometer reading as captured during an inspection. The PMVI data was provided on an incremental basis monthly. Driving Reports were calculated on the basis of the difference between two odometer readings over a period of time. Similar to the DIT Data Loader, the PMVI Data Loader Integration Tests required the solution to ingest, decipher, clean and store the imported data in the Datawarehouse for Driving Report generation.

5.1.3. Data Import

The timing and format by which Vehcon received data from both the PMVI and DIT varied. Initial files were provided at various times, with some inconsistencies present in the format of data fields (e.g. multiple formats for dates) in the files. This provided some challenge for the vendor and made the process of ingesting and making the data usable far more complex. It is noted that the instance of inconsistencies improved somewhat over time, as did Vehcon's ability to flag and handle variations.

As part of both Unit and Integration Test, Vehcon manually received data exports from both the DIT and PMVI, the former in a CSV format and the latter in a txt file. This data was then verified and imported into the Datawarehouse.

5.1.4. DIT Data Loader

Table 1 highlights the Data Load and Cleaning Tests carried out on the DIT Data as part of integration testing. The Data Cleaning Tests used real imported data run against BRs and SRs to exclude all defective data records and verify all eligible records which could be used to generate a DR.

Table 1: DIT Data Loader Tests

DESCRIPTION	COMMENTS
15 Business Rules/Requirements were applied specifically to DIT data across 21 tests/filter IDs	BR_Part1_12, BR_Part1_16, BR_Part1_17, BR_Part1_19, BR_Part1_24, DL.CRD.5, DL.IRD.1.10, DL.IRD.1.12, DL.IRD.1.13, DL.IRD.1.2, DL.IRD.1.3, DL.IRD.1.4, DL.IRD.1.5, DL.IRD.1.6, DL.MRD.1.1
7 of these tests/filters were removed/eliminated¹ based on examination of the data	Filters 4, 5, 6, 7, 17, 19 and 20 were either removed or not used
14 Filter IDs were then explicitly tested with a Test Data set	
Several cycles of testing were conducted to demonstrate test defects and issues were fixed	Implemented 3 rd party data sources for required EPA and GVWR data; added processing to harmonize multiple date formats used in source data; improved handling of improper data types.
The Expected and Actual test results were captured by Vehcon in a series of Test Result Reports	All Test Results were reviewed by the Test Team. For a listing of the Data Cleaning requirements and tests for DIT data, see Appendix A.3.3
On Test Cycle 5 all tests passed	

5.1.5. PMVI Data Loader

Table 2 highlights the Data Cleaning Tests carried out on the PMVI Data.

Table 2: PMVI Data Loader Tests

DESCRIPTION	COMMENTS
5 Business Rules/Requirements were applied specifically to PMVI data across 15 tests/defect IDs	DL.IRD.2.2, DL.IRD.2.4, DL.IRD.2.7, DL.IRD.2.8, DL.IRD.2.9
6 tests/defects were removed/eliminated based on examination of the data	Defects 9, 10, 11, 13 and two other non-numbered defects were either removed or not used
9 Defect IDs were then explicitly tested with a Test Data set	
Several cycles of testing were conducted to demonstrate test defects and issues identified were fixed	Added processing to harmonize multiple date formats used in source data; improved handling of improper data types; harmonized inspection station codes.
The Expected and Actual test results were captured by Vehcon in a series of Test Result Reports	All Test Results were reviewed by the Milestone Test Team. For a listing of the data cleaning requirements and tests for PMVI data, see Appendix A.3.3
On Test Cycle 5 all tests passed	

¹ A number of Business Rules and System Requirements evolved or became incorporated into other rules or requirements or were ultimately made redundant throughout the testing process. This information is captured in the RTM maintained by the Vendor

6. End-to-End Testing and Small Scale Operational Trial (October-November 2019)

End-to-End (E2E) testing was a limited scale test of the system from the uploading of real data from DIT and PMVI through production of Driving Reports, concluding with verification of Driving Reports against the source data. The Small-Scale Operational Trial (SSOT) included mailing those E2E Driving Reports generated by the system from real data to volunteer participants within HDOT. E2E testing and SSOT were conducted together—the first full end-to-end test of the system using the system to create Driving Reports for the 51 volunteers from within HDOT.

See Appendix A.3 for greater details of Integration Testing.

6.1. Purpose

The purposes of the E2E/SSOT were to:

- ▶ Exercise the entire driving report solution from end to end. The output Driving Reports was reviewed in final (PDF) form by the project team to verify that all was in order before the reports were mailed to the volunteers.
- ▶ Gather vehicle owner (end user) feedback from a limited and controlled target population. Each driving report printed and sent via mail (USPS) by the printers, then opened and read (experienced) by the end user. The vehicle owner could then take the Driving Report survey. In addition to the standard survey questions for the public, the SSOT volunteer was asked to provide feedback on the clarity of the Driving Report and survey.

6.2. Steps to Produce the Driving Reports

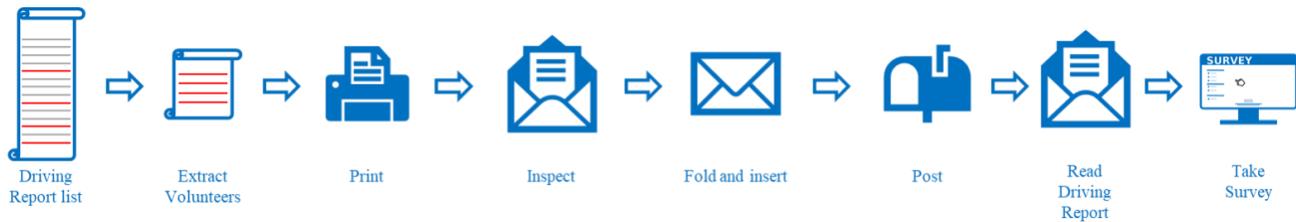
A small number of volunteers received the first Driving Reports. This first wave of volunteers was sought via an internal email sent to HDOT employees and project subcontractors.

- ▶ 51 volunteers were recruited

A full Driving Report cycle was executed (using Sept 2019 PMVI/DIT data), and the 51 volunteer's vehicles were extracted.

- ▶ 7 of the 51 had vehicles for which a DR would not be produced as they had insufficient PMVI odometer readings required to generate a report, an ineligible address as determined by NCOA, negative mileage, and one registration was inactive. These were valid exclusions, based on the business rules.
- ▶ The 44 remaining volunteer's driving reports were then generated and submitted (via secure FTP) to Cardinal Services for printing, folding and insertion into windowed envelopes.

Figure 2: Process Overview for Part 1



6.3. Inspection

Milestone first reviewed the Driving Report Data File generated by Vehcon to verify that the eligibility criteria was met and calculated fields were correct (miles traveled, potential road usage charge and estimated gas tax)

Milestone then reviewed the proofs generated by Cardinal for both types of individual Driving Reports (Driving Reports for gas/diesel powered vehicles and Driving Reports for electric vehicles). These proofs comprised of scans of a sample of printed Driving Reports generated from the Driving Report data file. The review allowed the Test Team to verify that the printing services were correctly calibrated to print the variable data on the preprinted Driving Report shells.

The Test Team then inspected the printed Driving Reports on Cardinal’s premises to conduct an individual eyes-on inspection of the Driving Report before they were inserted into envelopes, in advance of them being mailed.

6.4. Tests Conducted

- ▶ Validation of requirements as recoded in RTM
- ▶ Eyes-on tests of Driving Reports
 - > Visual examination of address detail and QR code visible in correct location
 - > Driving reports printed double-sided
 - > Visual appearance of driving report matches specification for template, color, data placement, font etc.
 - > Driving Report data for vehicle owner was correct (this was done in conjunction with a review of the source data).
- ▶ Envelopes successfully delivered.
- ▶ Recipients of the driving report find the Driving Report to be clear, understand that their feedback was being requested via the survey, were able to navigate the online survey, and understood the survey questions.
 - > Adjustments were made to the survey based on respondents’ feedback
- ▶ SSOT volunteers whose vehicles were not eligible to receive a Driving Report were asked to take the version of the survey meant for those who did not have a Driving Report in-hand and to provide feedback on whether they were able to navigate the survey and understood the survey questions.
- ▶ Troubleshoot any Driving Reports returned to HDOT by the Post Office.

► Test of the QR code scanning and posting of returned mail back to Milestone.

6.5. SSOT - Results of 'Eyes-on' Tests

TEST	PASS QTY	FAIL QTY	COMMENT
# of DRs produced	44	0	2 segments: 42 non-EVs + 2 Electric Vehicles
Address in correct location	44	0	
QR code readable by smartphone?	44	0	
Printed double-sided	44	0	
Correct template used	44	0	Incorrect template used for first round EV testing; corrected and passed re-testing.
Colors correct	44	0	
Fonts correct	44	0	
Static data correct	44	0	
Dynamic data correct	44	0	
Printing Alignment with template	44	0	Did not pass first round; corrected and passed re-testing
Survey Responses received	18		Time to take survey including the 5 extra questions was 8 – 12 minutes.
Returned mail	1		One address undeliverable

REQ. NO.	DESCRIPTION	QTY PASS	QTY FAIL	COMMENT
MD.BCD.1	Build complete DR data set	1/1		Vehcon confirmed all records were included
MD.BCD.2	Use applicable RUC and gas tax rates	44/44		All counties and all segments checked
MD.BCD.3	Generate pseudorandom 5-digit Report IDs, one per DR (1:1 with VIN)	44/44		Clarified that report ID would NOT include segment number as a 6th digit
DRG.CRD.1	Compute miles between odometer readings	44/44		Vehcon confirmed odometer readings were correct
DRG.CRD.2	Compute RUC charge as mileage x RUC rate (state and county)	44/44		
DRG.CRD.3	Identify DR data range based on odometer timestamps			N/A for the SSOT based on the limited data set. However, this was checked and confirmed for the initial batch of 1,000 DRs from the production data set.
DRG.CRD.4	Compute fuel consumed using combined EPA	44/44		Test Team performed accuracy check – based on the source EPA data licensed from DataOne.
DRG.CRD.5	Compute fuel tax as gallons used x fuel tax rate (state and county)	44/44		
DRG.CRD.6	Identify RUC and fuel tax rates on DRs	44/44		
DRG.GDR.1	Generate DR data files per segment	44/44		
DRG.GDR.2	Generate DR print data file	44/44		
Business Rule				
1.11	"County" for RUC purposes = county indicated by registration address			This was verified by unit test for BR 1.52.
1.40	County RUC and fuel tax rates will be on the DR	44/44		
1.44	DR "Period" is the time between the odo readings (for non-fleet reports)	44/44		
1.51	Rounding rules	44/44		Checked to match BR rounding rules.

7. Lessons Learned and Recommendations

Based on all phases of testing, but especially the SSOT, the following observations & recommendation were made.

7.1. Overall Process

- ▶ Turn-around times for data sources and print services took longer than expected. Plan accordingly.
- ▶ Template configuration tracking log introduced to ensure all parties involved were working from the latest version.

7.2. Driving Report Layout

- ▶ DR generally well received
- ▶ Discovered that the font size used to display state and county rates was too small and might be difficult to read for elderly readers.
- ▶ Discovered that the default QR code could not be used for variable information so an additional QR code was added to the right of the address field.

7.3. Driving Report Content

- ▶ Eliminate other ambiguous characters and numbers from the Report Number
- ▶ DR content and instructions sufficiently clear to recipients based on survey data
- ▶ Following feedback obtained during the SSOT survey, 1 FAQ entry on page 2 rewritten to provide more information on the per-mile rate

7.4. Survey

- ▶ Survey questions and lengths were appropriate
- ▶ Survey questions clarified
- ▶ URL back to hiruc.org added at the end of the survey

Appendix A Testing

The Appendix is organized as follows:

- ▶ Appendix A.1 contains details of Unit Testing.
- ▶ Appendix A.2 contains details of Integration Testing.
- ▶ Appendix A.3 contains details of End to End Testing and the Small Scale Operational Trial.

A.1. Unit Testing

Unit tests are conducted for each application at the component or sub-component level. Example: for the Data Warehouse application, separate unit tests will be conducted for the Data Loader and Data Merge components

Tests can be automated or manual. Manual unit tests are generally specified for “observable data”.

Automated unit tests are generally specified for API testing.

Unit Test - HIRUC Data Loader

- a. **Scope:** Ensure that the Data Loader accepts and “cleans” input data from PMVI and DIT sources. Defects at this level are determined by evaluating what validation of the source data is required to implement the Business Rules during downstream processing.
- b. **Test Method:** Manual
- c. **Result Method:** Pass/Fail per data element (compare actual vs. expected output)
- d. **Test Description**
 - > A sample input data set is created, including “good” records in addition to records with known defects.
 - > The input records are selected to cover a range of possible input and output values. An expected output result is manually calculated.
 - > The test file is processed. The test output is compared to the expected output. Results are recorded pass/fail for each field.

Reference: UnitScript_HIRUC_DataLoader_DIT.xls (attached)
UnitScript_HIRUC_DataLoader_PMVI.xls (in process)

Requirements/Business Rules Validated: DL.CRD.1, DL.CRD.2, DL.CRD.3, DL.CRD.4, DR.CRD.5, DL.CRD.6, BR.1.1, BR.1.16, DR.1.17, DR.1.24, DR.1.49, DL.IRD.1, DL.IRD.2, DL.IRD.3, DL.IRD.4

Unit Test - HIRUC Data Merge

- a. **Scope:** Ensure that data from the DIT and PVMI data sets is properly merged by VIN. Defects at this level are determined primarily from the Business Rules.
- b. **Test Method:** Manual
- c. **Result Method:** Pass/Fail per data element (compare actual vs. expected output)

d. Test Description

- > Similar to the DataLoader process. However, the Data Merge testing is done using multiple (time-sequential) data inputs from both data sources and the output is checked after each new data import.

Requirements/Business Rules Validated: DM.MRD.1, DM.MRD.2, MD.SD.2, MD.SD.3, MD.SD.4, BR.1.1, BR.1.5, BR.1.6, BR.1.7, BR.1.8, BR.1.9

Unit Test – Master Database

a. **Scope:** Ensure that the Master Database view of the Merged Data complies with the specifications.

b. **Test Method:** Manual

c. **Result Method:** Pass/Fail per data element (compare actual vs. expected output)

d. Test Description

- > The Master Database comprises a specified “view” of the Merged Data. The unit testing simply verifies that the view matches the specifications.

Requirements/Business Rules Validated: Same as “Data Merge”

Unit Test – Invoice Eligibility

a. **Scope:** Ensure that the DR Generator correctly selects eligible records from the Master Database for generating invoices, per the Business Rules.

b. **Test Method:** Manual

c. **Result Method:** Pass/Fail per data element (compare actual vs. expected output)

d. Test Description

- > Similar to the Data Loader process.

Requirements/Business Rules Validated: MD.IEV.1, MD.IEV.2, MD.IEV.3, MD.IEV.4, MD.IEV.5, MD.IEV.10, MD.IVS.3, MD.IVS.4, MD.IVS.5, BR.1.13, BR.1.18, BR.1.19, BR.1.21, BR.1.22, BR.1.23, BR.1.27a, BR.1.27b, BR.1.46, BR.1.47, BR.1.52, BR.1.53, BR.1.54, BR.1.55, BR.1.56, BR.1.57

A.2. Integration Testing

Integration tests combined units and tested them as a group using real data.

Test Method

- ▶ Upload DIT and PMVI data
- ▶ Verify that files are correctly imported into the system.

Test Files

DIT Loader

FOLDER WITH TEST DATA AND RESULTS	COMMENTS
DIT Data Loader - Error Codes.xls	Lists the validation tests applied to DIT data, and the associated error codes
DIT_Loader_Test_5_13Sep.csv	Lists DIT input records used in test file w/ descriptions of defects and expected/actual error codes
DIT_Loader_Test_5_Raw.txt	Input file for the test
dit_2_validation_results_Test5.csv	Output file for the test, including results for each validation test by error code

PMVI Loader

FOLDER WITH TEST DATA AND RESULTS	COMMENTS
PMVI Data Loader - Error Codes.xls	Lists the validation tests applied to PMVI data, and the associated error codes
PMVI_Loader_Test_5_16Sep.csv	Lists PMVI input records used in test file w/ descriptions of defects and expected/actual error codes
PMVI_Loader_Test_5_Raw.csv	Input file for the test
pmvi_2_validation_results_Test5.csv	Output file for the test, including results for each validation test by error code

Requirements/Business Rules Validated: Same as for Data Loader – Unit Test

A.3. End-to-End Testing

End-to-end testing involved re-validating requirements in a full end-to-end manner.

A.3.1. Driving Report Generation Test Report

The following table lists all requirements related to merging DIT and PMVI records, and analyzing DR Generation per the business rules.

REQT ID	BRIEF DESCRIPTION
BR 1.12	VIN is the primary identifier for a vehicle, not license plate
BR 1.13	One DR per vehicle during Part 1
BR 1.19	Vehicle must have DIT status = "A" to receive DR
BR 1.21	If registration address changes but owner name and county are the same, not considered a change in ownership history for DR purposes
BR 1.22	If owner name changes, it is considered a change in ownership history for DR purposes
BR 1.23	If registration address changes, owner same, but county changes, then it is considered change in ownership history for DR purposes
BR 1.27a	Vehicle must have odo readings, with same ownership, at least 8 months apart to receive a DR
BR 1.27b	Vehicle must have odo readings, with same ownership, no more than 30 months apart to receive a DR
BR 1.46	Only one DR per vehicle owner-address combo (by registration info)
BR 1.47	A non-fleet DR with > 100,000 miles reported should not be sent

REQT ID	BRIEF DESCRIPTION
BR 1.52	If registration address county doesn't match vehicle inspection county, a DR cannot be created
BR 1.53	If current mailing address county (per NCOA address) doesn't match vehicle registration county, a DR cannot be created
BR 1.54	If a PMVI inspection record for a given VIN pre-dates the earliest available DIT record for that VIN, the ownership at the time of that PMVI inspection record will be assigned per that earliest DIT record.
BR 1.55	Vehicle ownership at the time of a PMVI inspection record will be assigned per the info in the DIT record that equals or immediately precedes the inspection date.
BR 1.56	A DR will only be issued to the current owner of the vehicle, even if enough data exists to generate a DR for a prior owner.
BR 1.57	A registration status of "I" does not indicate a change a change in vehicle ownership or registration address
DM.MRD.1	Merge DIT and PMVI records per business rules
MD.IEV.1	Determine if DR can be generated based on Business Rules
MD.IEV.2	Identify which vehicles already had a DR generated
MD.IEV.3	Minimum data required for DR generation
MD.IEV.10	Report DR metrics including reasons why no DR generated

Test Method

- ▶ Create sample "raw input" files with a series of DIT and PMVI records over time
- ▶ Verify that the DIT and PMVI records are correctly associated per the Business Rules
- ▶ NOTE: License plate numbers are for reference only, for easier identification when scanning records. They are not used to merge records. VIN is the only value used to merge records.

Test Files

- ▶ DIT Input
 - > TestSet2G_hdot20160116
 - > TestSet2G_hdot20180501.txt
 - > TestSet2G_hdot20180701.txt
 - > TestSet2G_hdot20190101.txt
 - > TestSet2G_hdot20190401
 - > TestSet2G_hdot20190601.txt
- ▶ PMVI Input
 - > Test2G_PMVI_20160101_20190930.csv
 - > LateLoad_Test2G_PMVI_20190701_20190731.csv
- ▶ Output
 - > TestSet2G_driver_report.xls

A.3.2. Data Import

Tests related to importing of raw data files from DIT and PMVI.

REQT ID	BRIEF DESCRIPTION	NOTES
DL.IRD.1	Initial import of DIT data	
DL.IRD.2	Initial import of PMVI data	
DL.IRD.3	Periodic import of DIT data	
DL.IRD.4	Periodic import of PMVI data	
DL.CRD.1	Archive raw data	Raw data maintained in xxx_0_raw tables
DL.CRD.4	Standardize odo timestamp formats	

Test Method

- ▶ Upload DIT and PMVI data
- ▶ Verify that files are correctly imported into the system.

Test Files

	FILE	COMMENT
DIT Input	HDOT20180827.txt	Sample file as received from DIT
DIT Output	DL_1_dit_0_raw.csv	File after import from DB table
PMVI Input	HI_Stations_Inspection_20190902_20190914.csv	Sample file as received from PMVI
PMVI Output	DL_1_pmvi_0_raw.csv	File after import from DB table

A.3.3. Data Cleaning

Tests related to cleaning raw data (DIT & PMVI) to remove records with missing, invalid, or incomplete data. Used same test files as above, only to clean data.

REQT ID	BRIEF DESCRIPTION	NOTES
BR 1.12	VIN is the primary identifier for a vehicle, not license plate	Applies here because VIN-decoded data required for validation
BR 1.16	Vehicle Type is not used to determine DR eligibility	
BR 1.17	Vehicle must have EPA fuel rating to be eligible for DR	Implies MY1981+ and approved vehicle classes
BR 1.24	If registration address is not in HI, the vehicle is not eligible for DR	
BR 1.49	Only odo readings in miles (not km) are acceptable for DR use	
DL.CRD.2	Exclude incomplete or unsuitable data	Multiple validation tests; refer to SRS and Test Files for details
DL.CRD.3	Standardize address fields	For NCOA deliverability check only

REQT ID	BRIEF DESCRIPTION	NOTES
DL.CRD.5	Decode VINs	
DL.CRD.6	Report data quality metrics	
MD.IEV.4	Vehicle must comply with requirements in Biz Rules to get a DR	
MD.IEV.5	Odo readings must comply with requirements in Biz Rules to get a DR	