TECHNOLOGY DEVELOPMENT AND SYSTEM INTEGRATION FOR A VEHICLE MILES TRAVELED BASED REVENUE COLLECTION SYSTEM PROTOTYPE

Final Report

Developed for

The Oregon Department of Transportation
Road User Fee Task Force
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Introduction

The Oregon Department of Transportation (ODOT) is required by House Bill 3946 to begin the implementation of a pilot alternative road/highway revenue collection system. These pilot systems are to be designed to test alternatives to the current system of taxing highway use through fuel taxes. One alternative being considered is a Vehicle Miles Traveled (VMT) based fee.

This project (to be referred to as the VMT Prototype Project) has focused on the development of a working prototype of an *electronic* revenue collection system based on the VMT principle. This project was necessary since Commercial-Off-The-Shelf (COTS) technology with the required functionality is not currently available. Development of this working prototype consisted of both technology development and technology integration into a working system (a specific combination of technologies and their integration into a working system will be referred to as a *technology configuration)*. The objectives of VMT Prototype Project were to develop, integrate, test, and document two specific technology configurations that incorporate multiple concepts for on-vehicle mileage collection devices, and fee calculation and collection. This was done to demonstrate the feasibility of an electronic revenue collection system, and to gain further understanding of the actual advantages and disadvantages of various technologies and concepts.

This report is an executive summary of the VMT Prototype Project. Accompanying this report is a set of documents that provides detailed information on various system components. This report presents a summary of the following topics in the order listed.

1. A summary of project documentation where more detailed information can be found.
2. Recommendations.
3. Test results summary.
4. Additional development requirements.

Throughout this report it will assumed that the reader is familiar with the technology configurations developed and the various on-vehicle mileage collection devices developed. For a detailed description of the technology configurations the reader is referred to "Functional Requirements and Technical Specifications for GPS/AVI-based and Odometer/AVI-based On-Vehicle VMT Collection and Transfer Devices, and their Technology Configurations – V1.3". This document accompanies this report.

Summary of Project Documentation

The following table lists the documentation that accompanies this final report and a brief description of their contents. All version numbers listed are final versions for this project.

Document	Description
Functional Requirements and Technical Specifications for GPS/AVI-based and Odometer/AVI-based On-Vehicle VMT Collection and Transfer Devices, and their Technology Configurations – V1.3	A description of the technology configurations developed, and the functions that must be performed by the system components. A list of technical specifications for system components and specific functional requirements.
Central Database Documentation Version 1.4	Specific details for the database developed as part of the GPS-based technology configuration.
Local Database Documentation Version 1.4	Specific details for the database developed as part of the Odometer-based technology configuration.
OSU Software Documentation Version 1.4	Specific details for the software developed as part of the GPS-based and Odometer-based technology configurations. This software was developed to integrate the various system components used in each technology configuration.
Test Plan Document Version 1.0	Documentation of the test design to assess the performance of the technology configurations.
Test Results Document Version 1.0	Detailed documentation of the test results and analysis from executing the test plan for performance assessment of the technology configurations.

Recommendations

During the testing of the GPS-based and Odometer-based technology configurations different strengths and weaknesses of each system were revealed. The weaknesses discovered are summarized in the following table. For each item listed an assessment is included as to whether further development will eliminate the weakness. The recommendations presented will assume that correctable weaknesses are fixed.

Technology Configuration	On-Vehicle Device	Weaknesses	Correctable with Development
GPS-based	GPS-Only	1. Easy GPS signal blockage affects mileage collection accuracy. 2. Less reliable data transfer (compared to Odometer-Based technology configuration). 3. Poor mileage collection in some conditions. 4. Lengthy signal acquisition from "cold starts" affects mileage collection.	1. No 2. Yes 3. Partially 4. Partially
	GPS-Odometer	1. Easy GPS signal blockage affecting accuracy of mileage collection. 2. Less reliable data transfer (compared to Odometer-Based technology configuration). 3. Poor mileage allocation to zones in some conditions. 4. Lengthy signal acquisition from "cold starts" affects mileage allocation to zones. 5. More difficult installation than GPS-Only devices.	1. Yes - Default zones may be used to maintain accurate total miles collected. 2. Yes 3. Partially – Default zone may be used. 4. Partially – Default zone may be used. 5. Yes.
Odometer-Based	Odometer Only	1. More difficult installation than GPS-Only devices. 2. Violation detection is difficult with local databases. 3. No practical multi-zone (within OR) mileage collection.	1. Yes 2. Yes – but requires a central database 3. No

In the table above, a partial correction to a listed weakness means that improvement is possible, but that the weakness will still occur to some degree. The overall impact of partial corrections to an identified weakness on the operation of the technology configurations will require additional testing.

Our recommendation for a long term VMT-based revenue collection system is the GPS-based technology configuration that uses the combined GPS-Odometer on-vehicle device. This recommendation is based on the following:

- As a long term system that may possibly be used by multiple states, the GPS capability provides a good solution for defining zones (area and time period combinations) that does not require an extensive hardware infrastructure (i.e., wireless communication devices defining geographic areas).
- GPS technology will only improve in the future, which will reduce the impact of any GPS related weaknesses identified.
- The odometer capability of the on-vehicle device always ensures reliable total mileage collection. Default zones or other methods may be used when a GPS signal is lost or has not been acquired to maintain accurate total mileage collection.
- The central database feature of the technology configuration can generate information useful for identifying drivers/vehicles with broken mileage collection devices and/or drivers tempering with an on-vehicle device.

Test Results Summary

This summary of test results will present "high level" results for mileage accuracy collection, technology configuration transaction reliability, GPS signal blockage, data transfer disruption. For a detailed description of the test procedures see "Test Plan Document Version 1.0". For detailed test results the reader is referred to "Test Results Document Version 1.0". Both documents accompany this report.

Mileage Accuracy Collection

This test collected data on the accuracy of mileage collection for the various on-vehicle mileage collection devices used in the technology configurations. Tests were conducted in a variety of weather and terrain conditions. Two devices used a connection to the vehicle speed sensor to collect mileage. One device was the "odometer only" device used in the odometer technology configuration. The second device (used in the GPS technology configuration) used the speed sensor information to collect mileage, and GPS technology to allocate the mileage to pre-defined zones (a combination of geographic area and time period). For the odometer only device the total mileage collection was 100% accurate for the purposes of a VMT revenue system. For the second device mileage collection was less than 100%, but this was only because the device did not have a "zone" to accumulate mileage in the case when a GPS signal was lost. This is straightforward to correct. Given this correction to the second type of device 100% accurate mileage collection is to be expected since vehicle odometers use the same methods to collect mileage.

The on-vehicle device using GPS technology to estimate miles traveled was less accurate under certain conditions. Inaccuracies are caused by a combination of initial signal acquisition time and a loss of the GPS signal while driving. The worst accuracy occurred

while driving in heavily forested, mountainous terrain during heavy rains. A summary of the mileage collection results is presented the following table.

Device Type	Route	Avg. Approximate Percent of Miles Collected (vs. vehicle odometer)
GPS-Only	Corvallis (Small city environment)	100%
	Forested and Mountainous	75%
	Downtown Portland (Large city urban environment)	94%
GPS/Odometer Hybrid	Corvallis (Small city environment)	100%
	Forested and Mountainous	72%
Odometer Only	Corvallis (Small city environment)	100%
	Forested and Mountainous	100%

The mileage accuracy for the GPS-only units and the GPS/Odometer hybrid units was not statistically significantly different. This was because the current GPS/Odometer hybrid units did not collect mileage when a GPS signal was not received. If this feature of the device is changed so that mileage is always collected, the device will perform similar to the odometer-only device.

Technology Configuration Transaction Reliability

In this test fueling transactions with each technology configuration were simulated. Vehicles with the appropriate on-vehicle device were driven and parked in front of the fuel dispenser simulator and a transaction was simulated. These transactions required initiation by an "attendant" at the fuel dispenser simulator. This initiation occurs by "swiping" a credit card, or by pressing a "pay inside" button on the simulator. A complete transaction requires the following steps to be executed:

1. Transaction initiation.
2. Read of mileage data from the on-vehicle device.
3. Communication with remote central database to retrieve prior mileage data (GPS technology configuration).
4. Calculation of the VMT fee and the display of the fee on the fuel dispenser simulator.
5. Acceptance of fee by the attendant.
6. Simulated fueling.
7. Completion of transaction.
8. Updating of the central database mileage data (GPS technology configuration).

9. Updating the mileage data on the on-vehicle device (odometer technology configuration).

A transaction was determined to be successful if all of the prior steps were performed successfully.

15 transactions with each technology configuration were simulated. For both technology configurations, 13 of the 15 transactions (87%) were successful.

When transaction failures occurred, the cause of the failure was always determined to be an unsuccessful reading of mileage data from the on-vehicle device (step 2 above).

These test results clearly indicate that additional development for improved reliability of mileage data reading is required before any testing with actual drivers is performed. Furthermore the transaction reliability tests were conducted in a controlled environment where the relative positioning of the on-vehicle device and wireless data reader antennae was consistent.

GPS Signal Blockage

This test evaluated the ease and effectiveness that a user can prevent on on-vehicle device from receiving a GPS signal. In this test the GPS antenna was covered with a small piece of aluminum foil and the affect on the GPS signal (previously acquired by the on-vehicle device) was recorded. In all cases the signal blockage was immediate and effective. This result can have a very large impact on the effectiveness of on-vehicle devices that use GPS technology to estimate vehicle miles traveled.

Data Transfer Disruption

This test evaluated the ease and effectiveness that a user can prevent on on-vehicle device from having its mileage data read when parked in front of a reader at a fuel dispenser. In this test the antenna of the fixed wireless reader at the fuel dispenser was covered with a piece of aluminum foil and the affect on data transfer was recorded.

In all cases the effect of adding the aluminum foil was complete communication blockage between the fixed minion (wireless reader at the fuel dispenser) and the gateway minion (which is the pathway to the POS system). This communication blockage prevents any successful transaction requiring a VMT fee.

Additional Development Required

Additional development of the technology configurations will be required before the technology configurations can be tested with actual drivers. A list of these items is presented in the following list. The items listed (with the exception of items 11-13) are judged to be required if a technology configurations is to used be used by actual drivers.

The list is organized in three sections corresponding to the three major components of a technology configuration.

POS System

1. Test recovery procedures for common infrastructure failures (e.g. power outages, failure of POS system) are required.

2. Credit authorization development may be necessary depending on the service stations participating in the user testing phase.

3. Modify the Latitude POS system to return the amount of fuel purchased to the OSU Software when the VMT = $0 and the fuel tax is applied.

On-vehicle Devices/AFX Application Software

4. Improve data transfer (mileage data transfer from vehicles when fueling) reliability.

5. Develop required packaging and determine final installation methods and location.

6. Modify the GPS antennae to be less bulky and more discreet. Determine final installation methods and location.

7. Modify the on-vehicle device antennae used for data transfer. The current antenna is a single loose wire. Determine final installation methods and location.

8. Modify the on-vehicle devices to store mileage in non-rectangular zones. Also increase the capabilities to include more than three zones (if required).

9. Modify the on-vehicle devices so that they do not erase memory when power to the device is lost. This includes mileage data and calibration data.

10. Develop the system for more robust data transfer to accommodate various vehicle parking positions (relative to a fuel dispenser).

11. Add the capability to download zone information through the wireless readers.

12. Improve response times for data requests from the on-vehicle devices.

13. Develop a non-visual application for increased speed.

OSU Software – Central Database

14. Modify the OSU Software to pass VIN or device ID to Latitude for use in Latitude error recovery procedures.

15. Develop and test recovery procedures for common infrastructure failures (e.g. power outages, failure of POS system).

16. Develop the central database system to handle multiple users and sites.

17. Upgrade to commercial version of SQL used in the central database

18. Clearly define all reports to produce and all data to store in the central database.