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The IntelliDrive SM Logo is a service mark of the U.S. Department of Transportation.
1 INTRODUCTION

1.1 Document Purpose
This document describes the Concept of Operations (ConOps) for the Vehicle Infrastructure Integration (VII) for Safety, Mobility and User Fee program for the Minnesota Department of Transportation (Mn/DOT). The ConOps describes the current state, establishes the case for change, and describes the desired system in terms of its features and operations.

1.2 Background
The concept of VII was developed from previous intelligent highway vehicle programs including the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, The Transportation Equity Act for the 21st Century (TEA-21) of 1997, and finally the Intelligent Vehicle Initiative (IVI) that was created through TEA-21. The concept continues to evolve, and the U.S. Department of Transportation (U.S. DOT) has recently rebranded VII as IntelliDrive℠. IntelliDrive programs seek to improve traffic safety and mobility while enhancing commerce in the areas in which they will be implemented. In broad terms, IntelliDrive programs envision a communications infrastructure that includes elements of vehicle-based communication units or on-board equipment (OBE), static roadside sensors and communications or roadside equipment (RSE), and the centralized network that manages the exchange of data. The various OBE will be able to communicate from vehicle to vehicle and to the RSE using various wireless communications, potentially including Dedicated Short Range Communications (DSRC).

The goals of Minnesota’s VII for Safety, Mobility and User Fee project are to:

- Evaluate the effectiveness of in-vehicle signing for improving safety using localized applications.
- Fill the gap between the existing IntelliDrive Proof of Concept demonstration and future funding decisions.
- Determine if the in-vehicle signing approach being developed could be used to implement additional IntelliDrive applications.
- Assess if the proposed IntelliDrive application could be used to implement mileage-based user fees.
- Assess the viability of a non-network IntelliDrive safety application, especially for rural deployments.
- Demonstrate the proposed IntelliDrive approach for providing location-specific traveler information and collecting vehicle probe data.
- Assess the feasibility of using consumer devices for implementing IntelliDrive applications.

The VII for Safety, Mobility and User Fee project work is being divided into two phases. Phase I consists of tasks necessary to identify where deployment will take place, why the deployed system is necessary, what the proposed system should
do, when the system should be deployed, and how the system should work. This Concept of Operations, the preliminary requirements, and the evaluation approach developed in Phase I will provide the basis for Mn/DOT’s decision to proceed with Phase II. Phase II will be focused on the actual detailed design and implementation of the system as well as a complete evaluation.

1.3 Document Overview

The remainder of this document consists of the following sections and content:

Section 2 (Current System or Situation) of the ConOps describes the current situation with respect to the system or situation (either automated or manual) as it currently exists. When systems or functionality do not currently exist, the document describes the situation that motivates development of the proposed system.

Section 3 (Justification for and Nature of Changes) of the document describes the justification for and nature of the proposed changes. This section identifies deficiencies of the existing situation and the benefits of change.

Section 4 (Concepts for the Proposed System) describes the proposed system that would result from the desired changes. This is, necessarily, a high-level description, indicating the operational features of the system when fully deployed. This represents a long-term vision, not a description of the initial deployment.

Section 5 (Operational Scenarios) of the ConOps contains operational scenarios for the system. A scenario is a step-by-step description of how the proposed system might operate and interact with its users and its external interfaces under a given set of circumstances. The scenarios tie together all parts of the proposed system, the users, and other entities by describing how they interact.

Section 6 (Summary of Impacts) of the document describes the operational impacts of the proposed system on the users, the developers, the maintenance organizations, and the support organizations. This section may also identify temporary impacts on stakeholders that are a direct result of the transition from the old system(s) to the new system.

Appendix A (Background of Mileage-Based User Fees) describes the various approaches to and prior experiences with mileage-based user fees demonstrations in the U.S. and other countries.

Appendix B (Definitions, Acronyms, and Abbreviations) provides definitions for the terms, acronyms and abbreviations used throughout the document.

Appendix C (References) provides full citations for documents referenced in this Concept of Operations.

1.4 System Overview

Mn/DOT’s IntelliDrive system is proposed as a key element of the State’s efforts to establish a mileage-based vehicle user fee system, as well as to provide in-
vehicle signing services to motorists, which include enhanced safety features and driver information.

An IntelliDrive system could potentially provide services to benefit motorists. Through an in-vehicle device, messages could be provided to the driver such as location information, traveler information, travel times, vehicle probe data, and in-vehicle signing to supplement current roadside signing. Features such as these could provide the driver with enhanced safety as well as useful travel and navigation services. Additionally, a non-network IntelliDrive safety application, especially for rural deployments, will be assessed.

Vehicle taxation and fee collection is currently being revisited, as newer technologies, fuels, and vehicle types have brought into question the traditional methods of collecting roadway user fees. Newer vehicle types such as hybrids and electric cars have significantly higher gas mileage, or in some cases do not use gasoline, and increasingly comprise a higher percentage of vehicles on the State’s roads and highways. Under the existing fuel-based tax system, the necessary roadway revenues will potentially decrease as newer vehicles use less fuel. A fee based on mileage would be one means of ensuring that needed tax revenues continue to fund the roadway system as vehicle types and fuels change over time. Additionally, drivers would be charged on a per-usage basis, meaning that drivers who utilize the roads to a greater degree would provide more of the revenues needed for maintenance, whereas people who drive less would not be required to pay as much in the way of fees.

This Concept of Operations establishes the foundation for design and development of an IntelliDrive system that would address both the state and federal user fee collection as well as provide such aforementioned services to motorists. Although these capabilities might apply to a wide range of vehicle classifications, the initial demonstration will be limited to passenger cars, pickups and vans. Core components of the IntelliDrive system are envisioned to include, without limitation:

- In-vehicle signing that provides safety alerts to the driver based upon information contained within the vehicle, received from the roadside, and received from remote back office system(s).
- Location-specific traveler information with probe data that provides the driver with current traffic information and provides vehicle probe data from the vehicle to a back office system.
- Mileage-Based User Fee (MBUF) that accumulates miles driven in specific zones and reports this information to a back office system.
- Communications between the vehicle and the roadside, between the vehicle and appropriate back office system(s), and between components with the vehicle.

Development of the Concept of Operations is the first step in the systems engineering process (described in the following sections) that will be followed from concept, through design, implementation, operation and maintenance of the IntelliDrive system.
1.5 *Referenced Documents*

Full citations for the documents referenced in this Concept of Operations can be found in Appendix C, which also includes documents that have not explicitly been referenced, but contain additional information relevant to the project.
2 THE CURRENT SITUATION

This section of the ConOps describes the current state of transportation funding and IntelliDrive-related operations in Minnesota.

2.1 Background and Description

2.1.1 Transportation Operations

**Safety Zones and Alerts**

Currently, fixed static roadside signs are used for work zones, speed zones, school zones, curve warnings, and intersection warnings. Variable message signs, both permanent and portable, are used to supplement the fixed static signs in providing temporary and real-time messages to motorists. In addition, Mn/DOT has also experimented with dynamic Intersection Warning Systems (IWS) to provide additional alerts to motorists approaching intersections.

**Traveler Information**

Minnesotans benefit from a variety of highway traveler information services. Traditional publishing and broadcast media sources (newspaper, radio, and television) continue to provide a general view of incidents and roadwork that is widely available to the public. Mn/DOT provides a more detailed view of road and traffic conditions through its substantial investments in 511® telephone services and an associated website at [www.511mn.org](http://www.511mn.org). The raw traffic data and camera images are collected at the Mn/DOT Regional Traffic Management Center (RTMC) and processed into traveler information products for the website and 511 services. Mn/DOT can publish traveler information from the RTMC to its variable message signs throughout the state.

Mn/DOT also makes its traffic data freely available to commercial value-added information service providers. These providers generally integrate Mn/DOT’s information with their own sources and provide information back to broadcast media or through their own dedicated traffic information services. These services are typically made available through satellite and FM-based radio systems to in-vehicle telematics systems or aftermarket personal navigation devices.

2.1.2 Transportation Funding

The Minnesota Constitution provides the main framework for highway funding, establishing three highway user taxes and dedicating the revenue to transportation purposes. MnPASS and the Metropolitan County Wheelage are additional

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1. Minnesota Department of Transportation, *Concept of Operations, Intersection Warning System*
2. Minnesota Constitution, article XIV
sources of revenue. State statutes further specify formulas for allocation of revenue and various requirements as such.3

**Motor Fuels Excise Tax**

The following information is described in Minnesota Statutes, Chapter 296A and Section 168D.04.

The motor fuels excise tax is imposed on fuels used in highway vehicles, aircraft, boats, snowmobiles, and all terrain vehicles (ATVs) at a per-gallon rate and collected from fuel distributors. In general, distributors collect and remit the tax on or before the 23rd day of each month. According to the Minnesota Tax Handbook there are 464 petroleum distributors and 204 special fuel dealers. The tax rate depends on how the fuel is classified under state law.

Revenue collection is administered through the Minnesota Department of Revenue and Minnesota Department of Public Safety. Revenue from motor fuels excise taxes is allocated to the Highway User Tax Distribution Fund (97.024%), the Special Revenue Fund - for boat and forest road usage (1.616%), and the Natural Resources Fund - for snowmobile, all terrain vehicle, and off-road vehicle usage (1.360%).4 A portion of motor fuel tax revenue is attributed to non-highway recreational use, such as in motorboats, snowmobiles, and ATVs. That revenue goes into dedicated Department of Natural Resources funds for those respective activities.5

**Motor Vehicle Registration Tax**

The State imposes a registration tax (also known as tab fees) on motor vehicles in Minnesota. The annual tax applies to passenger vehicles as well as trucks and other vehicles that use the state’s highways. An exception is vehicles owned by government agencies (including school buses).

For passenger vehicles, the rate depends on a combination of the vehicle’s original value and its age. Vehicles are taxed at $10 plus 1.25 percent of the base value multiplied by a depreciation factor.6 Trucks and buses are taxed on the basis of weight and age; farm trucks pay a reduced weight-based tax. Motorcycles pay a flat tax of $10 annually.

Revenue collection is administered through the Minnesota Department of Public Safety and distributed to the Highway User Tax Distribution Fund. Any person who registers a motor vehicle in the state pays the registration tax; currently 4,400,000 passenger cars, pickup trucks, and vans; 800,000 trucks, tractors, trailers, and buses are registered. The tax is paid when first registered to use the public roads and annually thereafter upon renewal.7

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4. Minnesota Department of Transportation, *Minnesota Tax Handbook*

5. *Minnesota Statute § 296A.18*

6. *Minnesota Statute § 168.013*, subd. 1a

7. Minnesota Department of Transportation, *Minnesota Tax Handbook*
**Motor Vehicle Sales Tax**

The motor vehicle sales tax (MVST) is a 6.5-percent tax applied to the sale of new and used motor vehicles. It is imposed instead of the general sales tax and is based on the purchase price of the motor vehicle. MVST is collected by auto dealers or when the vehicle is registered. Tax paid to other states is credited under certain conditions.

Historically, MVST revenue was divided between transportation projects and the general fund. Voters in 2006 approved a constitutional amendment that gradually dedicates all MVST revenue to transportation purposes. The amendment specifies that 63.75 percent must be dedicated to transportation in fiscal year 2008, growing by 10 percent per year until reaching 100 percent in fiscal year 2012. It also requires that “no more than 60 percent” of the revenue go to highways and “not less than 40 percent” go to public transit.

Legislation in 2007 established an MVST phase-in schedule that specifies the actual division between highways and transit. In fiscal year 2012, after the phase-in, the revenues will be distributed 60 percent to highways and 40 percent to transit, with the transit portion divided into 36 percent for the metropolitan area and 4 percent for greater Minnesota. Minnesota Department of Public Safety is responsible for administration of the revenue.

**Metropolitan County Wheelage Tax**

The Wheelage tax applies to motor vehicles kept in a metropolitan county that has adopted the tax. Anoka, Carver, Dakota, Scott, and Washington Counties have imposed this tax and residents pay $5 per registered motor vehicle per year. The Minnesota Department of Public Safety collects the tax at the time of registration when the motor vehicle is first registered and annually thereafter upon renewal. The tax revenue is then transferred to each county. Revenue is distributed to the County Road and Bridge Fund.

**MnPASS**

The I-394 MnPASS project currently employs congestion pricing on high occupancy toll lanes. Along with the I-35W high-occupancy toll (HOT) lane conversion that began September 29, 2009, Mn/DOT will introduce priced dynamic shoulder lanes (PDSL). To use the MnPASS system, drivers must open a MnPASS account and obtain a transponder. Tolls are pre-paid and deducted from the account balance. The transponder is a small battery-powered radio toll collection device with a monthly fee of $1.50 for each MnPASS transponder being leased. The device mounts to the windshield. Fees are based on traffic levels in the express lanes to ensure traffic flows of 50-55 miles per hour. Tolls

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8. Minnesota Statute § 297B.02
9. Minnesota Statute § 297B.09
10. Minnesota Department of Transportation, *Minnesota Tax Handbook*
11. Minnesota Statute § 163.051
12. Minnesota Department of Transportation, [http://www.dot.state.mn.us/planning/stateplan/pdfs/5%20Transportation%20Funding.pdf](http://www.dot.state.mn.us/planning/stateplan/pdfs/5%20Transportation%20Funding.pdf) (accessed April 21, 2009)
also depend on where motorists enter and exit, and trip length. Tolls average $1 - $4 during rush hours (maximum of $8) and fees are posted on overhead dynamic message signs at entrances to the HOT lanes.  

2.1.3 IntelliDrive SM Programs
As mentioned in the Background discussion in Section 1.2, IntelliDrive SM (VII) programs have been a subject of intense industry research in recent years. In general, IntelliDrive solutions implement communication between vehicles, and between vehicles and the roadside infrastructure, using various technologies—advanced wireless communications, on-board computer processing, advanced vehicle sensors, GPS navigation, smart infrastructure, and others—to provide a framework for safety enhancements, improved mobility, and increasing driver convenience. A description of the various programs and demonstration projects, both completed and currently underway, is beyond the scope of this document, but easily referenced. The U.S. DOT IntelliDriveSM website provides a gateway to the relevant resources. In the context of Minnesota’s program, this body of research provides standards, lessons learned, and practical experience with some of the applications of interest to Mn/DOT.

2.1.4 Mileage-Based User Fees (MBUF) Approaches
Mileage-based user fees can be implemented in a variety of ways. They can be limited to specific areas or facilities or they can be very comprehensive. MBUF can be collected based on simple odometer readings or can be calculated based on careful evaluation of all travel done by a vehicle. They can be a flat fee for each mile driven or can be varied by time of day, class of road, geographic area, or direction of travel. It may even be feasible to set separate prices for each lane of a road. They can be the same for all vehicles or varied based on vehicle characteristics. Appendix A – Assessment of Alternative Approaches provides a background discussion and review of MBUF concepts.

At this time, Vehicle Miles Traveled (VMT) fees are not commonly used in the United States to finance roadway costs. However, certain types of tolls effectively function as mileage fees, there have been a number of experiments with distance-based charges, and several states have used weight-mile taxes for heavy vehicles.

2.2 Stakeholders
One of the issues to be addressed in this Concept of Operations is determining and defining the system’s key stakeholders. By establishing key stakeholders, the system’s primary and secondary goals and objectives can be better understood. Additionally, ongoing input can be solicited from these stakeholders to narrow the focus and refine the system’s design, resulting in an IntelliDrive system that will achieve maximum benefit to the State and its residents.

Drivers – Vehicles that use the State’s roads include the typical variety of cars, trucks, buses, commercial tractor trailers, construction vehicles, and others. The

drivers and/or licensed owners of these vehicles will benefit from services and safety features provided by IntelliDrive applications, and may also be assessed mileage-based fees through the use of IntelliDrive technologies.

**Traffic Managers and Planners** – One of the many potential benefits of IntelliDrive technologies would be the enhanced abilities to report and record real-time traffic data. This capability could serve as a valuable asset to those who are responsible for the planning of roads and highways, as well as for traffic management centers.

**Traffic Data Providers** – These agencies are responsible for acquiring and reporting traffic data, such as real-time traffic statistics that may be helpful in determining traffic patterns and trends. They may be able to utilize IntelliDrive technologies to supplement current methods and thus enhance data collection.

**Department of Transportation** – Mn/DOT is responsible for traffic management, planning, and data collection, as well as maintenance of the existing network of the State’s roads and highways.

**State, County, and Municipal Road Engineers** – These engineers are responsible for designing both new roads and upgrades, and for maintenance of existing roads. Understanding traffic patterns of different vehicle types provides additional input to enhance their design capabilities. In-vehicle alerts from the IntelliDrive system can also provide these engineers with additional means of communicating potential hazards and enhancing the safety of motorists.

**Department of Revenue** – This State department is currently responsible for the collection of fuel taxes and subsequent distribution of funds.

**Department of Public Safety** – This State department issues license tabs and collects registration and license tab fees. DPS is also responsible for the safety of motorists on the State’s roadways, which could potentially be enhanced through the use of IntelliDrive systems.

### 2.3 Technologies

#### 2.3.1 Personal Navigation Devices (PND) and Related Products

PNDs are established aftermarket products with many competitive offerings from multiple vendors. Many of these devices are designed specifically for in-vehicle use and can utilize GPS to provide accurate location information, generally to road-level resolution. Typically PNDs include mapping and navigation software and may provide other location-based information. Real-time traffic data, if available, is typically received via FM radio-based signals from service providers such as FM TMC Traffic, XM NavTraffic, and MSN Direct.

Some newer PNDs are able to exchange traffic data with an information service provider through two-way data communications over cellular networks. The traffic data is provided from data aggregation servers which can provide “real-time” routing based on aggregated data and current vehicle location. There are a
limited number of providers of this level of service to date. Two examples are Dash Express (www.dash.net) and TomTom High Definition Traffic™.

Other mobile devices also may have navigation capability. For example, mobile phones may have navigation applications and provide real-time communications, but have limited display capabilities. In addition, PDAs may have navigation applications but are less likely to have real-time communications.

2.3.2 Dedicated Short Range Communications (DSRC)

A communications technology method currently utilized in similar IntelliDrive applications is DSRC. DSRC can provide the communication interface between a vehicle and the roadway infrastructure, or between a vehicle and other vehicles. In addition to IntelliDrive applications, DSRC may be utilized in such applications as electronic toll collection, emergency warning systems, traffic signal preemption for emergency vehicles, and automated gate access for parking or restricted access areas.

DSRC is somewhat related to RFID technology and its specifications include communication protocols and message sets for communication between the vehicle and the roadway. Originally, DSRC was facilitated in the 915-MHz band, which was shared with applications such as pagers, garage door openers, and cordless telephones. More recent DSRC communications standards in the U.S. reside in the 5.9-GHz band with a 75-MHz wide spectrum. Typical data rates are in the narrowband range, though broadband data rates may be available in some cases. DSRC can provide one-way or two-way communications.15

2.3.3 Automatic Vehicle Location (AVL)

AVL systems provide enhanced fleet management capabilities by delivering real-time location information for vehicles within a fleet. This information is delivered to a central dispatch location through a GPS receiver on the vehicle, a communications link between the vehicle and the dispatcher, and PC-based reporting software at the dispatch console. The communication system is typically facilitated over narrowband wireless communications, which may consist of a cellular phone service provider or a two-way mobile radio system.

GE’s telematics products are also capable of providing AVL services. ACS is another provider of satellite-based fleet management technologies, such as mobile communication networks and passenger information features, which are intended to assist public transit and public works systems with increased efficiency of fleet management.16

2.3.4 Mileage Reporting and Telematics

Mileage reporting devices are currently in use by various programs. The MyRateSM system has been deployed by Progressive Insurance specifically for

mileage-reporting in support of an insurance rate plan.\textsuperscript{17} The system extracts data such as mileage, hard starts and stops, and time of day from the vehicle’s on-board diagnostic (OBD-II) port. The system does not include GPS, and therefore does not report location. Data is sent by a cell phone transceiver imbedded in the device. In the UK, Norwich Union insurance has, since 2006, subsidized the installation of telematics units in vehicles for its rate optimization plan, but the program has been put on hold until units are built into vehicles by manufacturers. Other insurance companies are looking at similar plans, some of which may include location reporting by GPS. Similar systems could be used for mileage-based fee collection, with or without location reporting.

Vehicle integrated telematics systems are available in the marketplace. Ford’s SYNC\textsuperscript{®} feature uses Bluetooth communications to provide vehicle display and sound with connected portable devices; the latest versions of SYNC provide GPS location data, traffic, and telematics.\textsuperscript{18} GM currently has more than two million subscribers for its OnStar service, which offers in-vehicle safety, security, and information services through the use of GPS satellite and cellular technology, to link the vehicle and driver to the OnStar Center. At the OnStar Center, advisors offer real-time, personalized assistance.\textsuperscript{19} In addition, the State is provided with notifications of air bag deployments from OnStar vehicles. Toyota’s Safety Connect\textsuperscript{TM} and Lexus’s Enform\textsuperscript{TM} are set to launch on late summer models. This factory installed hardware will include features such as Automatic Collision Notification, Stolen Vehicle Location, Emergency Assistance Button, and Roadside Assistance.\textsuperscript{20}

GE's Telematics Services product unites vehicle performance data with existing fleet-wide information through its myDashboard\textsuperscript{SM} web-based analytical and reporting tool to provide customers with simultaneous access to fleet vehicle and people-related information at a single location. The intent of the system is to allow customers to determine and analyze key factors impacting their company's operating costs and service delivery.\textsuperscript{21} Information provided through the use of GE’s telematics system may include metrics such as total distance driven, fuel use, drive time, speeding, idling, and carbon dioxide emissions. The system is also intended to help customers streamline planning and scheduling.\textsuperscript{22}

\textbf{2.3.5 Electronic Tolling}

Modern toll collection systems utilize technologies involving vehicle-mounted transponders to charge tolls to vehicles without exchange of cash. The latest systems can charge tolls to motorists without the vehicle operator having to slow down from cruising speeds. Such examples of electronic toll collection systems currently in operation include MnPASS, the E-Z Pass system currently utilized by

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several states on the east coast, the Kansas Turnpike Authority’s K-Tag, and the SmartTag system used in Virginia.23

With the current system employed by MnPASS, account holders install a transponder (a small battery-powered radio toll collection device), on their vehicle’s windshield. The transponder communicates to the network when a vehicle is driving on the tolled section of the roadway. Charges are based on traffic volume levels in the toll lanes; the motorist is alerted when a toll has been successfully charged.24

Puget Sound Regional Council in Seattle, WA conducted a Traffic Choices Study.25 The primary aims of the Traffic Choices Study were to (1) accurately describe the behavioral response to the congestion-based tolling of roadways, (2) better understand issues of policy related to the implementation of road tolling, and (3) test an integrated system of technical solutions to the problem of tolling a large network of roads without deploying substantial physical hardware on the roadside.

Vendors that provide advanced products and/or services for electronic toll collection systems include T-Systems and Skymeter Corp. T-Systems has developed and administers the toll billing system on German motorways.26 Skymeter has a product called the In-Vehicle Sensor, which utilizes satellite-based communications to provide electronic tolling, and is not limited by the need for roadside infrastructure. Skymeter’s product can work with some tolling infrastructures, and can handle toll roads, zones, and parking areas, with a single device. Consequently, customers receive only one bill for all tolled applications through Skymeter. Additionally, sensors can also be used to gather anonymous trip data to help customers gain a better understanding of their system and its users. Drivers who use the sensor may be given incentives such as parking discounts.27

3 JUSTIFICATION FOR AND NATURE OF CHANGES

3.1 Justification for Changes

3.1.1 Transportation Funding

It is projected that revenues generated for transportation needs will not be sufficient to maintain the roadway system already in place, expand the system to accommodate future growth, and ensure that roads and bridges are safe. In particular, a major source of transportation revenue, motor fuel taxes, is expected to decline as a result of the shift toward more fuel efficient vehicles. In addition to concerns about ensuring adequate levels of transportation infrastructure investment, basing transportation funding primarily on a motor fuel tax conflicts with other high priority policies such as reduction of fuel use for environmental reasons and reduction of dependence on foreign oil. Mileage-based user fees, which would be possible under some IntelliDrive solutions, would generate revenue to fill the gap from the reduction of motor fuel taxes collected and would spread the costs of the transportation system across highway users regardless of how vehicles are powered. In addition, such fees would generate a more stable source of funding over time than motor fuel taxes.

3.1.2 Traveler Information

The traveling public continues to demand more accurate and timely information about traffic and weather conditions in order to increase safety and minimize travel times. Information available from media sources such as radio broadcasts is often not as accessible as desired (e.g. stations may broadcast traffic reports every 10 minutes) and may not be pertinent to current location and destination. In addition, information is typically available for only major routes. Other methods for accessing information include going to websites and getting information from cell phones, but these options are not feasible for drivers who are already in transit. More sophisticated in-vehicle solutions, like services providing traffic information on dedicated FM radio channels or over cellular data communications, are available, but have not yet seen wide adoption.

Ultimately, drivers would benefit most from having only traffic information that is immediately relevant to their current location, intended route, and destination. Information on current traffic conditions could be collected from many probe vehicles and integrated with traditional sources to provide a more complete, near real-time perspective. The integrated traveler information would be filtered for relevance and displayed or announced without unnecessary distraction to the driver—only as needed to assist in routing and destination decisions.

3.1.3 Safety Zone Alerts and Signing

While static roadside signs are the standard at this time, they have limitations in terms of being able to attract a driver’s attention or address current driver behavior. In some cases (intersection approaches, for example) drivers are provided only with specific regulatory instructions (“STOP”) and need more
information to make the best decisions as to how to proceed (for example, in judging the gap to an approaching vehicle). In other cases, warning signs are intended to apply only under certain conditions (“Bridge ices before road”), the presence of which may be unknown to the driver.

IntelliDrive technologies could provide the means to supplement these static signs with more specific signing within the vehicle. This guidance would be specific not just to the location, but to the specific traffic conditions that exist at the time the driver encounters that section of roadway.

3.2 Goals and Objectives

The goals of Minnesota’s VII for Safety, Mobility and User Fee work are to:

- Evaluate the effectiveness of in-vehicle signing for improving safety using localized applications.
- Fill the gap between the existing IntelliDrive Proof of Concept demonstration and future funding decisions.
- Determine if the in-vehicle signing approach being developed could be used to implement additional IntelliDrive applications.
- Assess if the proposed IntelliDrive application could be used to implement mileage-based user fees.
- Assess the viability of a non-network IntelliDrive safety application, especially for rural deployments.
- Demonstrate the proposed IntelliDrive approach for providing location-specific traveler information and collecting vehicle probe data.
- Assess the feasibility of using consumer devices for implementing IntelliDrive applications.

The goal of the Phase I work for the VII for Safety, Mobility and User Fee project is to identify where deployment will take place, why the deployed system is necessary, what the proposed system should do, when the system should be deployed and how the system should work. Phase I will formulate a scope of work for implementing all applications in Phase II. Phase II will focus on the actual detailed design and implementation of a demonstration project.

Phase II of the Mn/DOT IntelliDrive/VII program will demonstrate the operation of an aftermarket platform and supporting infrastructure for providing location-based safety, mobility, and user fee services. The platform will preferably be common to all three of these functions, and it is likely that some degree of hardware and software integration will be necessary in order to achieve this commonality. Infrastructure will include any roadside devices, back-end servers, software, and network services needed to support the application services.

Based on the Mn/DOT Request for Proposal (RFP) for VII Safety, Mobility and User Fee Technical Program, the objectives discussed throughout this section address:

- Mileage-Based User Fee
- Traveler Information and Probe Data
• In-Vehicle Signing

3.2.1 Mileage-Based User Fee (MBUF)

The objectives of the MBUF demonstration are to:

- Demonstrate assessment of mileage-based user fees using aftermarket navigation units
- Develop a business model for collection of mileage-based user fees

The selected system/device must be deployable, efficient, enforceable, accurate and able to verify mileage in the case of disputes.

Public Policy Perspective

In early 2007, Mn/DOT began assessing customer opinions and perceptions to a mileage-based user fee (MBUF). Findings indicate that Minnesota consumers are fairly unaware of how transportation is funded or how funds are spent. However, when it is explained to them, they understand that a sizable portion of funding comes from fuel taxes and that a transportation funding problem is almost a certainty in the near future. Given these findings, as well as growing concern about transportation funding at the national level, the need to explore MBUFs is becoming more pressing.

Traveling Public Perspective

The traveling public is concerned with having access to safe and reliable roadways that meet their mobility needs, but they also want to minimize fees and taxes. Fees and taxes must be perceived as fair and the methods for imposing such fees understandable and predictable.

Privacy of movement is a major concern to many drivers.

Transportation Operations Perspective

State agencies responsible for collecting MBUFs need the development and operation of the mileage-based revenue collection system to be cost effective, and also need the capability to adjust mileage fee structures and rates over time. Operations and collection services could be provided by third-party service providers to the state agencies, who would be similarly interested in system efficiencies.

Traffic managers want to be able to control traffic distribution and flows through use-based charges in order to relieve congestion and maintain free flowing traffic along various sections of roads and highways. These charges may vary based on particular geographical areas, types of roads and road segments, and times of the day and week.

3.2.2 Traveler Information and Probe Data

The objectives of the Traveler Information and Probe Data demonstration are to:
• Demonstrate collection of vehicle probe data and dissemination of route-specific traveler information using aftermarket navigation units
• Develop a business model for collection of vehicle probe data and dissemination of traveler information

The on-board device that provides traveler information must preserve the safety of vehicle operations, must not distract the driver, must ensure driver privacy and must accurately reflect real-time conditions.

**Traveling Public Perspective**

Access to better traveler information, including real-time traffic and road condition information related to current position and destination, is important to support optimal decisions on the part of vehicle drivers.

As mentioned previously, privacy of movement is a major concern to many drivers, and therefore any system that provides improved traveler information must also ensure privacy of movement.

**Transportation Operations Perspective**

*Traffic managers* are interested in current travel times of vehicles on arterials and collectors in order to be able to disseminate useful and accurate information to motorists. This information can provide motorists with the ability to select routes that may optimize travel times and avoid congestion. In addition, historic signal control delay data is necessary for traffic managers to calibrate signal controls on arterials.

*Planners* are interested in historical traffic data that includes such items as travel times on arterials and collectors, origin-destination data and trip charting data, and intersection turn data. Weather-related probe data has not been identified as a high priority to planners.

### 3.2.3 In-Vehicle Signing

The objectives of the in-vehicle signing demonstration are to:

• Demonstrate in-vehicle signing using aftermarket units
• Evaluate the effectiveness of in-vehicle signing for improving safety by using localized applications
• Determine what additional IntelliDrive applications may be developed from the in-vehicle signing approach
• Assess the viability of a non-network IntelliDrive safety application, especially for rural deployments

Most IntelliDrive signing applications can be done from roadside to vehicle, as opposed to having to communicate from an operations center. This application should not require a network connection to every roadside unit (RSU). In-vehicle signing could be the ultimate application, in that it could enable multiple safety and mobility applications. It is important that the safety of the vehicle operations is observed and that care be taken to avoid too many display features inside the
vehicle that may become a distraction to the driver. Similarly, the device may be
configured to alert only based upon specific vehicle conditions; for example, a
curve speed alert may be provided only if the vehicle’s speed is above an alerting
threshold.

**Traveling Public Perspective**

In-vehicle signing is expected to improve safety as drivers receive more and better
information than what is currently provided with static signing.

**Transportation Operations Perspective**

In-vehicle messages will need to be consistent with external messages and
messages should only be sent when they are warranted. Traffic engineers will
need to be able to keep signing up to date.
4 CONCEPTS FOR THE PROPOSED SOLUTION

This section describes concepts for the proposed system that respond to needs identified earlier in the document. Concepts are described as operational capabilities and are not intended to specify or imply particular designs or implementations.

4.1 Background and Description

Minnesota’s VII for Safety, Mobility and User Fee project will demonstrate and evaluate the ability to provide real-time safety, mobility and user fee information to a driver using an aftermarket in-vehicle device in communication with external information services. The specific applications that Minnesota envisions may include the following:

- Mileage-based user fee
- In-vehicle signing
  - Work zone alert
  - School zone alert
  - Speed zone alert
  - Curve warning
  - Intersection collision warning
- Enhanced traveler information

The system concept incorporates the in-vehicle device (comparable to the on-board equipment in the original VII concepts), external systems providing road conditions and local traffic control data (corresponding to roadside equipment capabilities in earlier VII schemes), back office systems to accumulate MBUF and probe data, and wireless and network communications to link those systems. The system will use DSRC for specific local safety functions such as intersection warning, but is not constrained solely to DSRC for communications. There is no presumption of an integrated or dedicated IntelliDrive network.

4.2 System Constraints and Assumptions

Previous demonstrations of IntelliDrive applications and MBUF systems, as described in Section 2, have developed new or customized hardware and software for vehicle on-board equipment and system communications. The intent of Minnesota’s IntelliDrive/VII program, however, is to leverage the diversity of commercial off-the-shelf (COTS) consumer electronic devices to reduce the time and cost of developing IntelliDrive and MBUF solutions. Many of the basic features needed for IntelliDrive applications—GPS functionality, high-speed communications, and user displays, for example—are widely available on personal navigation devices and mobile phones.

It is recognized that enhancements to COTS devices may be needed to fulfill the entire scope of Minnesota’s IntelliDrive/VII program. Some applications, for example, may need or benefit from a direct interface to the vehicle’s on-board diagnostic data. Implementing driver interfaces on the devices will, in many
cases, require new software. The level of detail needed to provide in-vehicle signing will likely require additional data on roadway features like signs and safety zones.

The use of the IntelliDrive systems to provide data for operational decision-making by both drivers and traffic managers constrains communications latencies. Probe data from the vehicle needs to be available to the traffic managers in the RTMC with latencies comparable to those from fixed vehicle detections stations in order to be useful in traffic management and travel time calculations. Traffic information provided by the RTMC to information service providers and drivers needs to be timely enough to be useful in driving decisions.

Figure 1 – IntelliDrive SM Concept using Aftermarket Navigation Device
4.3 **Odometer-Based Mileage Fee Implementation**

The base concept for implementing mileage-based user fees in Minnesota is to assess a mileage fee on all miles driven by vehicles registered within the state. The precise fee structure is yet to be determined by legislative policy and could vary among vehicle classifications. Unlike some other mileage fee concepts, MBUF in Minnesota is conceived to be a supplement to, and not necessarily a replacement for, motor fuel taxes.

Annual vehicle mileage and fees to be assessed will be determined from state-certified inspection of the vehicle’s odometer. Registered owners will report with their vehicles to the administrating service provider premises for odometer readings. The first reading following institution of the MBUF program would provide a baseline for fees to be due thereafter. The first year’s fees would be prorated based on the dates of odometer readings such that all vehicles would begin incurring fees as of the same date.
Figure 2 – IntelliDrive℠ Operations using Aftermarket Navigation Device
4.4 Opt-In State and Zone Discounts on Mileage-Based Fees

Minnesota will also provide an optional MBUF program in which mileage fees can be discounted relative to the base MBUF fee structure for miles driven out of the state and out of congested zones and time periods. Registered vehicle owners opting into the discount program will obtain a system from the MBUF administrative service provider that can determine and accumulate vehicle mileage in the applicable zone(s) based on location and time of day. Zones will be defined by policy decisions and may include, for example, country, state, congestion area, jurisdiction of roadway, or specific roadway segment. Any given mile of travel could fall into more than one zone simultaneously. Mileage fee rates could be discounted for each zone relative to the base MBUF fee structure. The owner can opt into the program at any time.

The MBUF in-vehicle system will be based on popular consumer electronic products. It will provide a display for driver information, a GPS receiver, and wireless data communications. The system will, at the driver’s option, provide displays of mileage fee rates and the current balance of the user fee account for that vehicle. It will also accumulate mileage and fees for reporting to the administrative service provider.

The system is obtained from the administrative service provider office and installed in the vehicle. The system receives vehicle data through a connection to the vehicle OBD-II port, which on U.S. light passenger vehicles is located under the dash near the steering column. Installation is simple, and can usually be performed by the driver from instructions to be provided by the service provider. Once installed, the system registers itself with the administrative service provider through its wireless communication capabilities.

In operation, the system compares the vehicle’s current location with the mileage fee zone maps to determine appropriate mileage fee rates. Drivers will not be charged by the state for out-of-state miles. Standard mileage fee rates will apply in congested zones and time periods, with reduced rates for travel in uncongested zones and time periods. The rate (and accumulated fees) can be displayed to the user at any time.

Accumulated mileage and fees are reported to the administrative service provider for billing. The specific reporting interval and billing mechanisms are yet to be determined. Reporting could be as frequent as each vehicle trip or as infrequent as once in each registration cycle. The actual frequency of reporting will depend on the communication capabilities of the system and must be consistent with the billing methods.

4.5 Safety Zone Alerting

The same aftermarket system that provides MBUF discount capabilities can be used to provide in-vehicle signing and safety zone alerts to drivers. The system would monitor the vehicle location relative to roadway features such that the driver can be alerted to potentially unsafe driving conditions. Visual and audible alerts would generally be provided only when safety limits were exceeded. Alerts
could be provided, for example, for speed zones, curve speed warnings, school zones, and road work zones.

The in-vehicle system will need timely communications with the roadside infrastructure to assure the relevance of its signing and alerts. The location of safety zones could generally be provided to the system as an enhancement to the standard map database and could be updated dynamically through the system’s wireless communications. Zones associated with fixed road signs, like speed limit signs and curve speed warnings, change infrequently. Some safety zones—school zones, for example—are physically fixed, but are active only at certain times of the day and week. Safety zones where the need for alerts is driven by traffic conditions, such as intersections with collision avoidance systems, would require direct communication with the associated traffic control devices to provide relevant in-vehicle signing. The University of Minnesota will provide the roadside portion of a Cooperative Intersection Collision Avoidance System for Stop Sign Assist (CICAS-SSA) to support the in-vehicle signing application for intersection warnings. Alerting for non-fixed zones—work zones and temporary speed detection zones, for example—would benefit from direct communications between the roadside and vehicle. DSRC was developed to fulfill similar types of operational communication needs and might work for these alerting applications in Minnesota.

4.6 Probe Data Collection and Traveler Information

An aftermarket in-vehicle system could gather probe data for traffic management applications and provide traveler information to the driver. As described earlier, similar services have become commercially available in recent years both as part of automobile manufacturer-affiliated programs and as independent services. Minnesota’s particular interest in these applications is focused on opportunities for sharing the in-vehicle system with MBUF and safety applications and on data integration with the DOT’s management and operations.

Probe data gathered by the system would, at a minimum, provide time-dependent location, speed, and heading data. These datasets could be provided from the system’s GPS capabilities. Fuller integration with navigation services on the system could provide direct measurement of travel times between specific points on the road network. A connection to the vehicle’s OBD-II data port could potentially provide additional probe data as described in the SAE J2735 specification for probe data messages. Probe data would be provided to a probe data aggregator through the system’s wireless data communications.

Probe data would be used by Mn/DOT’s RTMC to supplement traffic data currently received from other fixed vehicle detection stations and to provide new data types. Vehicle speeds, for example, could be used to validate existing traffic speed measurements and to provide speeds on road segments not currently instrumented, particularly on arterial roads. Direct measurement of travel times would be very valuable to transportation agencies in providing dynamic validation of travel times calculated from sensed traffic speeds. Other information available from the vehicle’s data bus could be valuable in providing weather and road
condition data. Transportation agencies could receive probe data directly, or a private service provider could receive probe data and provide aggregated data to the transportation agencies and travelers.

Traveler information enhanced by the aggregation of system-equipped probe vehicles could then be returned to those systems for driver presentation. Travel times and event alerts would be published by the RTMC for distribution to in-vehicle systems. Information relevant to the vehicle’s current position would be presented to the driver.

The operational focus of both probe data collection and traveler information publication requires that data be made available fast enough to support operational decisions by both the RTMC and drivers. In practice, the in-vehicle system’s wireless communications will need to support latencies on the order of two minutes or less for the data to have operational value. Archived probe data will also be valuable to planners in future traffic studies.

### 4.7 Government-Operated Business Model

A government-operated business model would require the federal and/or state government to contract with hardware and software vendors to build the systems, the roadside infrastructure, the back office operations, and the communications, all according to government specifications and requirements. In this model, the government agency would be responsible for operation, administration, and maintenance of the system, either using government or contract employees.

In this model, vehicle owners would make payments to the government agency for mileage-based fees and would be issued the systems and provided information from the government agency. Probe data and mileage data from the systems would be transmitted to the government agency. Data transactions between the system and the roadside and between the system and a center should adhere to government specified standards and as a result, would be consistent for every vendor of the system. System vendors may or may not be allowed to separately offer additional applications or services that use the system for a fee. Private sector participants are in a contractor/vendor role, selling products and services to the government for the government’s use.

### 4.8 Private Sector Business Model

In the private sector business model, the government agency defines the output requirements for the system which will be operated by a private entity. For example, the content and format of mileage usage data and travel time data for roadways would be required to meet agency defined specifications. The government would specify the required degree of accuracy, reliability, auditing capability, timeliness, etc., of the mileage and travel time data. In this model, the government negotiates rates to pay the private sector operating entity for the mileage usage data, the travel time data, and the systems. The private sector entity builds, operates, administers, and maintains the system using their own employees or subcontractor employees at their own cost. In this private sector model, the government agency would pay the private sector entity for the data and the
systems. There may be several competing private sector entities that are certified by the government as being able to provide the data under contract with the government. Each private sector entity under contract with the government may have its own method to collect data from the system to provide the government-requested data. The private sector entity profits through selling the data and the systems to the government. In this model, probe data and mileage usage data would be collected by the private sector entity rather than directly to the government. In this model, the private sector entities are service providers rather than serving only in the capacity of contractors/vendors.
5 SCENARIOS

5.1 Vehicle Owner Perspective

Jennifer lives in a Twin Cities suburb and drives about 12 miles to get to her workplace every day. She drops her kids at school on the way, and it generally takes about 25 minutes to get to work. On a bad day—an accident or bad weather—it takes a little longer.

Jennifer isn’t too concerned about the new mileage-based user fees being introduced in Minnesota. She understands the need to maintain roads, and it makes sense that there will be less money from fuel taxes as hybrid and plug-in electric vehicles become more common. The mileage fee seems like a fair compromise. It applies to every vehicle, no matter what kind of fuel it uses.

When Minnesota instituted mileage-based user fees, Jennifer went to the state-certified MBUF service provider office to have her vehicle's odometer read. She’ll be paying the mileage fee this year on all the miles she drives. It’s really that simple. Having the service provider read the odometer ensures timely and accurate reporting.

Jennifer is thinking that it might be worth it to opt into the mileage fee discount program. One of the guys in the office was talking about a system offered by the state that’s plugged into his car and lets him know what rate he’s paying as he drives. He gets discounts for driving at off-peak times and in less congested zones, and he doesn’t pay at all for miles driven out of state. The system also provides alerts on traffic conditions and safety zones.

Jennifer decides to stop by the MBUF service provider to enroll in the discount program. The service provider gives her a brochure on the program and a system that provides a dash-mounted display for traffic information, safety zone alerts, and real-time display of mileage fee rates. The system plugs into the OBD-II port underneath the dashboard of her car to get mileage data and communicates wirelessly with services that provide real-time traffic information and billing for the mileage fees. The installation was simpler than it maybe sounds.

The next morning, Jennifer leaves the house as usual. An alert pops up as she drives toward the kids’ school to remind her of the reduced speeds in the school zone—she was talking to the kids and driving somewhat over the posted school zone limit. This is a surprise, but a good one. It’s better to be reminded of safe driving behaviors than to be caught in a violation or an incident. On the other hand, no one wants a computer to nag them about their driving.

When she stops for coffee on the way to the office, Jennifer checks the program brochure to learn more about how the system works in the car. It says that the system will only alert the driver if the driving conditions—for a school zone, like speed and time of day—are outside posted limits. The warning at the school came up because her speed was too high at a time of day when students might be present. Alerts might also come at intersections, near work zones, on highway curves, or at any location with other posted warnings or limits.
The brochure also indicates that Jennifer can get current traffic information on the system. Sure enough, the traffic display shows traffic conditions and events around her current location. It also provides travel times for particular segments in the general area, like between major freeway interchanges. An accident is shown on the freeway she normally takes to work, so she decides to get back on the road and take an alternative route.

Over the next few weeks, Jennifer becomes more familiar with the system. It occasionally alerts her to potentially unsafe driving conditions—like that temporary work zone around some pothole repair—but not so much that it’s become annoying. The traffic information is accurate and always relevant to wherever she’s driving at the time. She’s also managed to reschedule some trips for a less congested time with a reduced fee rate.

At the end of the first month Jennifer gets an email billing notice from the service provider for the mileage fees. She clicks the link to pay the bill with her credit card and decides that it might be easier to just pay it once a year with her license tab fees. All in all, the mileage fee is a small price to pay for the benefits of better traffic information, alerts, and less stress in traffic.

5.2 **Administrating Agency Perspective**

A statewide network of service providers has been established to work with vehicle owners in administering the mileage fee program for the State of Minnesota. Each service provider office is required and certified by the state to adhere to the administrative policies prescribed by the state for the MBUF program.

As a result of instituting mileage-based fees for all vehicles registered in Minnesota, registered owners are required to appear at the service provider office with their vehicles for annual odometer readings. Fees are calculated for mileage accumulated since the last report. Mileage is also reported when the vehicle title is transferred to a new owner, assuring that mileage fees are charged to the owner of the vehicle responsible for that mileage.

The process for putting vehicles on the discounted fee program is only slightly more complex. An owner wanting to participate in the program comes to the office to obtain the in-vehicle system and the program brochure. Installation of the system is described in the brochure and can normally be performed by the owner. The system is self-registering with the back-office billing systems. Confirmation of the in-vehicle system’s operation can be verified in the back-office systems based on the vehicle identification number. The in-vehicle system communicates wirelessly with the back-office systems for mileage records, fee calculations and billing. Mileage fees are defaulted to the normal (non-discounted) rate in cases of system tampering or malfunction.

5.3 **Traffic Manager Perspective**

The Minnesota RTMC monitors traffic conditions, manages and responds to events, and provides information to the traveling public in the metropolitan Twin
Cities and across Minnesota. On this particular morning, an incident on one of the major in-bound commuting freeways has traffic at a complete stop. Information on traffic conditions has previously come into the RTMC from fixed vehicle detection stations, video cameras, and from state police reporting, but probe data from vehicles with the IntelliDrive systems has increased the volume of data available to the RTMC. Traffic managers are already seeing increased traffic on arterials around the incident location that were not previously instrumented for traffic monitoring.

This more detailed view of the incident has been enabled by improvements to the RTMC’s traffic management system to capture probe data from vehicles in the Minnesota program. The system is able to integrate the probe data with the fixed detection station data and synthesize reliable travel times along travel corridors throughout the state. Traffic managers have more data to work with and are able to provide a more comprehensive analysis of conditions and events. This enables them to provide a more specific response to events and improve the reliability of travel time estimates.

As operators get more data on the incident and reports come in from first responders, it becomes clear that this will take time to clear. The system generates new estimates of travel times along and around the corridor, and traffic managers update messages on message signs and on traveler information services. Drivers with in-vehicle systems receive alerts on the incident before encountering the backup and are able to make route decisions that reduce the impact on their travel times and the incident recovery time on the affected freeway.
6 SUMMARY OF IMPACTS

6.1 Impacts of Mileage-Based User Fee Implementation

Public Policy Perspective

Addition of MBUF to the provisions for surface transportation funding in Minnesota will require legislation to create statutory authority to collect and allocate those fees. This legislation might also include adjustments to the collection of other transportation-designated taxes and fees in the state.

Administrative Perspective

Implementation of legislative policies for MBUF will require the design of administrative processes supporting collection and allocation of MBUF. While the administrating agency would not be identified until that legislation is in place, administrative systems and services will have to be created, modified, or procured to support that agency. Once created, those systems and services will need to be tested. Support for operation of the administrative systems and services will be needed for as long as the fee is being collected.

As described in the Section 4.3 concept, MBUF administration will include regular odometer inspections for mileage baselines and fee collections. These inspections are likely to necessitate new or increased human resources and facilities for the administrating state agency or its contractors. The agency might also be responsible for distributing and supporting the in-vehicle systems described in Section 4.4 that support the zone discounting of the MBUF.

Traveling Public Perspective

Under the MBUF concept described in Section 4.3, owners of registered vehicles would be required to report with those vehicles for odometer inspections by the administrating agency. Policies regarding which types of vehicles are subject to the MBUF are yet to be determined. This would be a new responsibility for those vehicle owners that might not coincide with any other service or reporting opportunity. Owners would subsequently be responsible for payment of the MBUF itself.

Owners opting into the state and zone discounts on the MBUF described in Section 4.4 would be responsible for obtaining and using the in-vehicle systems supporting those discounts. It is also reasonable to expect that drivers may modify some of their driving behaviors in response to the mileage fee rate indications on the system. Knowing that their mileage fees can be reduced by avoiding trips in certain zones at certain times of day could alter driving patterns.

Transportation Operations Perspective

Transportation operations personnel will not interact directly with MBUF systems and services, and would be affected only indirectly by its implementation. Changes in traffic patterns may manifest themselves as larger numbers of drivers...
opt into mileage fee discounts and driver behaviors adapt to fee rate changes by zone and time of day.

Transportation Planning Perspective

Depending on how transportation funds are made available by public policy changes, planners may be affected by the relative levels of MBUF-related funds allocated to surface transportation projects.

6.2 Impacts of Traveler Information and Probe Data

Traveling Public Perspective

Drivers opting into the MBUF discount program will obtain access to enhanced traveler information through the in-vehicle system. This information, delivered in a timely manner, will enable drivers to make more informed travel decisions that ultimately may reduce their travel times.

Transportation Operations Perspective

Incorporation of probe data from system-equipped vehicles into the existing Mn/DOT RTMC systems and provision of suitably enhanced traveler information will require the design of new interfaces and algorithms. System components will have to be created, modified from existing capabilities, or procured to support those new functions. Once created, the new components and their integration with the existing RTMC systems will need to be tested. The new interfaces may increase operations support needed for the RTMC systems.

Once in place, operators in the RTMC may start to see changes in driver behavior and traffic patterns, particularly in response to incidents and events.

6.3 Impacts of In-Vehicle Signing

Traveling Public Perspective

Drivers opting into the MBUF discount program will see in-vehicle signing consistent with roadside sign on the system. Alerts to regulatory and warning signs based on traffic and road conditions may be provided to draw the driver’s attention to potentially unsafe conditions or behaviors. This information will facilitate driver awareness and safer driving decisions, especially in challenging conditions.

Transportation Operations Perspective

Mn/DOT, in cooperation with county and local traffic engineers, will have to identify locations and opportunities for which to provide in-vehicle signing. Standards for displaying the in-vehicle signing and alerting drivers to potentially unsafe conditions will be necessary, followed by design of specific interfaces for the in-vehicle systems themselves. The systems and services that support the creation, distribution, and management of in-vehicle signing will be created or
procured. Extensive testing of both the systems and the driver responses will be needed to ensure that the systems are fulfilling their intended purposes. The systems will require ongoing operations support and integration with existing road sign management processes to provide continued consistency between the roadside and in-vehicle signing.
APPENDIX A – BACKGROUND OF MILEAGE-BASED USER FEES

MBUF Approaches
Mileage-based user fees can be implemented in a variety of ways. They can be limited to specific areas or facilities or they can be very comprehensive. They can be collected based on simple odometer readings or can be calculated based on careful evaluation of all travel done by a vehicle. They can be a flat fee for each mile driven or can be varied by time of day, class of road, geographic area, or direction of travel. It may even be feasible to set separate prices for each lane of a road. They can be the same for all vehicles or varied based on vehicle characteristics.

VMT Fees
The simplest type of MBUF is a fee or charge that is based on the number of vehicle miles traveled (VMT). At the state level, it is likely that the state would want to differentiate between in-state and out-of-state miles driven. Charging for all VMT could be viewed as unfair for those with substantial out-of-state travel. Particularly if many states adopt such a system, there will be concern about the allocation of revenue. Under fuel taxes, the state tax on gasoline is collected based on the location of the service station. This works reasonably well for people on long trips since they are likely to purchase gas in some proportion to the miles driven in each state. However, people who live in one state and work in a bordering state may have substantial use of roads in a state where they seldom purchase fuel. For diesel use by heavy vehicles, the tax is allocated under the International Fuel Tax Agreement (IFTA) based on where the vehicle is operated rather than where fuel is purchased.

Facility Tolls Based on Distance
There is a long history of tolls being used to finance specific facilities. These tolls were typically used to raise revenue to finance the tolled facility. Tolls often vary by vehicle type but are otherwise flat. The toll could be based on distance in two ways. Setting toll booths at somewhat regular intervals creates a crude type of mileage fee. For limited access toll roads, a fee based on entrance and exit points can more accurately be set as a mileage charge. With GPS capabilities, toll revenue could be based on actual distance traveled on the toll facility.

Prices Set to Improve Management of the Road System
VMT charges could be varied based on level of congestion, class of road, road damage done by the vehicle, or pollution and other externalities generated by the vehicle. Such charges are fairly rare, but there is growing interest in using the price system to better manage the road system (CBO 2009).

The economically efficient set of charges would generate incentives for the most efficient use of the road system, but there are complications and trade-offs. Perhaps the most important complication is that the efficient prices may not
generate the appropriate amount of revenue. This question will be addressed later and the focus here is on the determination of efficient prices. For cars and other light vehicles, the primary concern is any impact on congestion during congested conditions. The impact on congestion will depend on the level of congestion, and this is likely to vary for several reasons. First, there is systemic congestion, which is associated simply with the number of people using the road. This is subject to certain patterns of congestion as well as to random variation. Second, there is bottleneck congestion, which is associated with capacity constraints on a road, either due to physical differences, such as reduced number of lanes, or operational conditions, such as on and off traffic. Finally, there is incident congestion, associated with accidents, weather, or other factors that may interfere with traffic flow (CBO 2009). When setting prices for congestion, there is a trade-off between the ability to manage congestion efficiently and the ability of the driver to make decisions based on the efficient price. Prices set in advance may not accurately reflect conditions at any given time, but prices that vary dynamically may not allow the driver sufficient advance information to change behavior.

Charges for externalities that vary with miles driven could also be included in efficient VMT fees. Externalities can be different under different circumstances and may be mileage-based or based on other characteristics, such as amount of fuel used (Parry et al. 2007).

For heavy vehicles the cost imposed on the road relates to the size of the vehicle and to the operating characteristics. Because of the size and possibly slower acceleration, more room for braking, and problems with steep road grades, heavy vehicles are often compared to light vehicles in terms of road capacity used by means of Passenger Car Equivalent (PCE) measures. The PCE will vary based on a variety of characteristics, including the level of congestion and steepness of road grade, and this may be the best determination for congestion-related charges to heavy vehicles. In addition, heavy vehicles cause substantial damage to road pavement based on the weight per axle and certain other characteristics of the vehicle. This damage also varies with the ability of the road to withstand heavy loads. Thus, the efficient charge for a heavy vehicle would also vary with the class of road, weight of the vehicle, and number of axles (Small et al. 1989).

**Review of U.S. Experience**

VMT fees are not directly used in most road finance in the U.S.; however, certain types of tolls effectively function as mileage fees, there have been a number of experiments with distance based charges, and several states have used weight-mile taxes for heavy vehicles. Table 1 summarizes U.S. and international experiences with mileage-based user fees and related programs.

**Oregon VMT Experiment**

The following is based on Rufolo and Kimpel (2008), Whitty (2007), and Kim et al. (2008). The Oregon mileage charging experiment has generated substantial interest. In the experiment, participating vehicles were charged a mileage fee and received a refund of the state gas tax when they fueled at participating stations.
Some vehicles were charged a flat fee for all miles driven in Oregon while other vehicles were charged a premium rate for driving in the Portland metropolitan area during weekday rush hours and were charged a discounted rate for all other driving in Oregon. Vehicles were not charged for driving outside of the state and did not receive rebates for gas taxes paid to other states. There are several distinct advantages of this system as a mechanism for collecting revenue. Since the fuel tax is the default, the majority of revenue for the system is collected from the distributors who pay the fuel tax. This substantially reduces the potential for evasion or need for enforcement mechanisms. People who do not pay the mileage fee, default to paying the gas tax. In addition, the state has limited need to audit or monitor individual motorists or vehicles. It should be relatively simple for a computer system to compare gas tax refunds with miles driven to flag vehicles with anomalies for audit. In general, the state would only have to regularly audit the service stations with respect to the net difference between the mileage fee collected and the gas tax included in the wholesale purchase of fuel. The system shows promise as a method to transition from the fuel tax to a mileage-based fee; and it could support congestion pricing at some point. Despite the positive aspects of the experiment, there appear to be both technological and non-technological issues that deserve further consideration.

While the system is compatible with congestion pricing, congestion pricing would only be feasible with most vehicles participating. Yet the system is projected to be installed on new vehicles. Since the phase-in period is expected to be fairly long, this does not seem to be a reasonable short-term system for using pricing to address congestion problems. Also, the system does not distinguish factors that affect the impact that a vehicle has on the level of congestion, e.g., class of road or direction of travel, although it does charge for each mile driven in the defined area.

The technological improvements required relate to the cost and reliability of the system. In general, there is going to be a trade-off between cost and reliability. For the system tested, estimates of the mileage by zone were compared to the odometer mileage for some vehicles and the differences were as high as 20 percent. In addition, the geographic refinement of the zones was limited. For a revenue collection system, users must be convinced that the system is fair, and discrepancies in the determination of location or mileage may create problems. Hence, costs may have to come down substantially to allow a system with enough reliability to be used for revenue collection, or some capabilities may have to be omitted during the phase-in. If the capabilities, e.g., for congestion pricing, are left out of the early vehicles, then the implementation for congestion pricing gets further delayed.

The system relied on Radio Frequency (RF) communication between the vehicle and the fuel pump. For fueling transactions, the signal strength was required to reach a pre-specified level before the vehicle was clearly identified as fueling at a specific pump. This appears to have resulted in a substantial number of transactions that were not identified as being for participating vehicles. Spacing of the pumps, the level of RF interference, and other factors may have affected the
reliability of the system, and failed connections created some problems for the system. If not identified as a participant, the vehicle was charged the state gas tax and not the mileage fee. At the next transaction, the mileage fee from the last identified connection would be charged, but the refund would only include the gas tax on the current purchase. The owner had to submit a receipt showing the gas tax paid in the interim fueling to get the appropriate refund of the state gas tax. Much greater reliability is needed for an operational system.

Miles driven with no GPS signal were not charged. The GPS system was left on at all times to minimize the number of miles driven that could not be allocated, but this resulted in battery problems for a large number of vehicles.

Behavioral responses may not all be positive. Even with a flat fee per mile that approximated the gas tax, some people reported reducing driving simply because they became more aware of short trips and cost. There was some evidence that the flat fee induced people to group trips. This reduced the total number of trips, but since drivers appeared to group these trips with their rush hour trip to or from work, it may have increased rush hour travel. If the grouping resulted in more travel on uncongested local streets, it would not be a problem; however, if the travel was on congested arterials or other roads, the flat fee pricing may have a perverse effect on congestion. This could be exacerbated if it increased the amount of stopping and starting, e.g., through more on-street parking, and further disrupted traffic. The effect of a flat mileage fee on rush hour travel should receive further analysis.

Finally, major oil companies did not agree to allow their gas stations to participate in the Oregon experiment. Since they represent the majority of stations, the reasons for their refusal should be clarified and addressed.

Puget Sound Regional Council

The Puget Sound Regional Council sponsored a project to equip vehicles with a device to track all road usage in the area and set prices based on the class of road and time of travel. Detailed information on all travel by a vehicle was collected and uploaded regularly by cellular transmission. The system is reported to have worked well, but specific information has not yet been released.

At this time, the final report of the experiment is still being prepared, but the preliminary summary identifies a number of issues to be addressed before the system can be implemented (Puget Sound Regional Council 2007). These include further refinement of the system and design of enforcement and billing systems. In particular, there was no enforcement mechanism in the design of the experiment and an enforcement system would have an additional cost. Dense road networks without access controls were identified as a concern for the pricing system. The trade-off between having data processed on the vehicle with summary data sent to the billing center versus uploading all data for processing at a central location was identified as having privacy implications as well as communication cost implications. The detailed information collected on travel did not appear to be a concern for the participants, but it would almost certainly be a concern if participation were not completely voluntary. Implementation of a full
scale system is projected to have a mechanism for non-participants that could also maintain anonymous usage. Also, the area subject to the pricing seems to have been limited by the storage capacity of the system. The cost of the initial installation of the GPS system and communication costs were identified as key concerns, but declining cost over time for each were also noted.

**Iowa Pooled Fund Study and Extension**

The Iowa Pooled Fund study designed a GPS-based system that could track miles driven by area and could include a variety of areas with varying degrees of overlap and separate pricing systems. All data is maintained in a secure environment, with only total amounts owed by the vehicle to each jurisdiction generally available. The data was uploaded regularly using a smart card system. If there were a dispute regarding amounts owed, the vehicle owner could decrypt the data to show detailed travel information (Forkenbrock and Kuhl 2002).

This system is undergoing extensive testing over a number of years and seven locations. It will be some time before the conclusions from this extended study will be available. However, the basic design is likely to follow that described by Forkenbrock (2008). It is likely to be somewhat different from the initial experiment. The on-board computer will have the capability to store polygons so that charges can be varied by geographic area. It is expected that there will be differentiation by state but that local governments could also add charges for travel within their jurisdictions. In addition, the computer will have the capability to use more detailed files to identify class of road, so that differential prices could be charged for different roads. For periods without a GPS signal, the information from the odometer will be used to generate charges, and the comparison between the GPS mileage and the odometer mileage will be used to monitor the system. Billing data will be uploaded once per month to a central billing operation. The billing center will only receive information on the total bill and the apportionment among jurisdictions. During the upload, updated fee files could also be sent to the vehicle. The fee structure could be specific to vehicle classes, with characteristics such as fuel efficiency and emissions affecting the rate charged.

Georgia tested a system similar to the Iowa one, but without the encryption, as a method to charge flat VMT fees. An extension appears to be having delays due to instability with the hardware and software problems.

**Pay As You Drive Experiments**

Several of the experiments in the Value Pricing program were designed to convert some of the fixed costs of driving to variable costs. These experiments used different types of technology and helped to identify some of the potential methods to collect the MBUF, as well as some of the potential drawbacks of these approaches. The Minnesota study used a commercial system that plugs into the OBD-II port to obtain mileage data and tracked total mileage and time for each trip. This allowed for differences in pricing by time of day, but would not allow for differences based on location of travel, nor class of road. In addition, data had to be manually downloaded, and the system is not compatible with all vehicles
A separate account must be set up for each participant and there would have to be a billing or payment system.

**Oregon Weight-Mile**

Oregon charges heavy vehicles a mileage charge that is based on the registered weight of the vehicle and the number of axles. The charge is intended to equitably allocate the cost of road damage among heavy vehicles since the amount of road damage increases with vehicle weight but decreases with additional axles for a given weight. The system is based on monthly or quarterly reports by owners of heavy vehicles. Only mileage totals are reported. The rate is based on the registered weight of the vehicle and the number of axles to avoid the need for detailed monitoring of load changes. Certain vehicles, such as log trucks, have the option of paying a flat fee, but most vehicles must pay the weight-mile tax. The charge is levied in lieu of the diesel fuel tax. Oregon does not levy a diesel fuel tax on fuel purchased for use in a vehicle paying the weight-mile tax. The mileage reports are based on owner fleet records and the system is well established (Rufolo et al. 2000).

**Review of International Experience**

**London, Singapore, and Other Cordon Pricing Experiments**

These systems are not distance-based. They charge a flat fee for either crossing a cordon or for any travel within the designated zone. The primary interest with respect to a distance-based system would be evaluation of the technology for use in enforcement for a distance-based system. For example, the license plate recognition system used in London is one possible method to enforce compliance with a mileage-based system. The license plate recognition system could identify vehicles traveling in the priced road system that had not registered and paid appropriate fees.

**German Truck Fee**

The German system levies a fee based on the road, distance traveled, number of axles, and emission class of the truck. The fee is charged on the autobahn system but has the potential to be expanded to other roads. Truck drivers have the option of paying for trip permits manually at various point-of-sale systems, or of having a GPS-based system installed that allows for automatic collection of the tolls. The large majority of tolls are paid using the GPS-based system. The system determines the location of the vehicle and uses the location information to determine tolls based on 5200 toll segments in the system. The information on tolls is then transmitted to a billing system. In addition to the GPS, the system has a dead reckoning capability for times when the GPS signal is not available. The cost of the system is paid by the toll authority but installation costs are paid by the user. The Global System for Mobile communications (GSM) is used to communicate with the computer center. The system has additional communication capabilities for enforcement and for interoperability with other European communication systems. The initial start-up had substantial cost overruns and the
units are fairly expensive (Samuel 2005 and Kossak 2006). The system used in the Puget Sound study is a simplified version of the German system.

Dutch Proposal

The Dutch have a detailed proposal to move to MBUF. However, there is still much uncertainty about the specifics of the system. They have compiled a substantial amount of information. It is still somewhat speculative, but they have done detailed cost studies and continue to move toward implementation. It appears that the intent to implement road pricing for heavy vehicles starting in 2011 has now been postponed.

Discussion of Issues

The MBUF will have to be collected and enforced. This has not been a concern for many of the experimental approaches since they did not actually collect any money from participants. The typical procedure was to set an endowment account that was expected to cover the charges a vehicle would incur with no change in miles driven. The mileage charges were then deducted from this account and any balance was given to the user at the end of the experiment. This procedure gave the marginal pricing incentives without creating actual cost or financial risk for the participants. However, it also meant that there did not have to be any bill paying mechanism nor any method to enforce collection when the bill was not paid.

As noted earlier, the Oregon system had a relatively simple mechanism for payment; the charge was adjusted at the pump when the vehicle was fueling. Under full implementation, virtually all collection activity would occur at the fuel pump, and most of the actual revenue would come from the fuel distributors, who would still be liable for the state fuel tax. All of the other systems require that some form of a bill paying system be implemented. In addition, some methods of enforcement and auditing will be required. Finally, some method of reconciliation for customers who dispute their charges must be implemented.

There are substantial trade-offs between system capabilities, cost, and complexity. The simple systems just keep track of total miles traveled. Somewhat more complex systems keep track of mileage by geographic area. The most complex systems are those that require identification of class of road. Aside from the need for more detailed information, the potential for error in identifying roads typically requires additional capabilities to improve accuracy.

Both the Oregon and Minnesota systems get data from the OBD-II port. It appears that the OBD-II port may be problematic as a general requirement. First, it was only required in vehicles starting in 1996, but some vehicles with the port do not meet all of the specifications. Both experiments had problems with certain vehicles due to issues with the OBD-II port. In Minnesota they were excluded from participation, and in Oregon these vehicles were equipped with an alternate system that simply used the GPS to calculate miles traveled. Also, in the Oregon experiment, there were discrepancies between the miles driven as calculated using speed data from the OBD-II port and miles from the odometer reading.
Any system used to collect revenue will be subject to evasion and avoidance behavior. Both may be relevant in terms of evaluating an MBUF system. Some systems will be designed to induce avoidance, e.g., congestion pricing systems; but others may induce inefficient behavior. For example, a system like Oregon’s, which charges by the mile in-state but has no charge for out-of-state mileage could induce a driver to make a long trip along the state border of Washington on the Washington side. This would reduce the amount of mileage fee owed to Oregon without affecting the gas tax rebate. Evasion is a larger problem. With a GPS-based system, evasion might be accomplished by blocking the antenna to prevent signal acquisition. Since signals may be problematic in some areas, such as those with large buildings or forests, it may be difficult to determine whether there has been purposeful interference or a natural problem.

There must be a mechanism for audit and reconciliation if there are differences between the amount that the system charges a motorist and their view of what the charge should be.

If integrated with the gas tax, the point-of-sale (POS) software requires substantial modification to allow the system to interact with the mileage fee system. Some determination of the cost for this conversion, and of who will be responsible, should be made. It would also be necessary to substantially improve the ability to detect which pump a vehicle is being fueled at, since missed reads create both an accounting and a customer relations problem.

Information on prices must be communicated to vehicles and displayed to drivers. There should also be a method to update information. This is likely to be necessary if there is any intention to change fees over time.

There are several equity issues that must be addressed. If the fee is simply a mileage fee for equipped vehicles, equity between equipped and non-equipped vehicles will be an issue. One possibility would be to refund an estimate of the gas tax based on miles driven and Environmental Protection Agency (EPA) mileage estimates. Other equity concerns relate to equity between vehicle classes, geographic equity, and equity relative to income.

If the system is to be used for road management, some determination must be made of how the system will be phased in and what level of coverage is needed to make the system effective. For example, congestion pricing is not likely to be effective unless most vehicles face the congestion charge.

There may be a need to get legislation or apply for existing exceptions allowing for a charge to be levied on the interstate system. The legislation creating the interstate system prohibited the use of tolls on the system to encourage interstate commerce. A number of toll roads were already incorporated into the system and were allowed to continue using toll revenue; however, roads built from that point on as part of the interstate system could not have tolls levied. ISTE A allowed for some exceptions to this prohibition, but it generally still prevails. For detailed discussion of the prohibitions, exceptions, and legal issues, see Fishman (2009), pp 20-28. For information on the use of tolls on the interstate system see FHWA (2009).
### Table 1 – Summary of Mileage-Based User Fee Experience

**METRICS**

<table>
<thead>
<tr>
<th>STUDY</th>
<th>Distance Metering</th>
<th>Communications</th>
<th>Data Processing</th>
<th>Invoicing</th>
<th>Collections</th>
<th>Vehicle Locating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota</strong></td>
<td>Yes, via odometer, calculation from vehicle speed, or GPS system</td>
<td>Undecided, but DSRC technology is desired on at least one application</td>
<td>On-board computer, roadside units, back-end servers</td>
<td>Electronic or paper billing could be used. May also tie into annual registration fee renewal</td>
<td>Options of paying online, automatic billing or paying at service center</td>
<td>Only if driver chooses to participate in the opt-in program based on GPS data</td>
</tr>
<tr>
<td><strong>Oregon VMT</strong></td>
<td>Vehicles were charged per mile driven</td>
<td>RF communications between vehicle and fuel pump</td>
<td>On-board computer calculates miles driven</td>
<td>User is not invoiced, but can check fees paid on fuel receipt</td>
<td>User pays mileage fee at the pump and is reimbursed for fuel taxes</td>
<td>In-vehicle GPS unit determines location of vehicle and number of miles traveled</td>
</tr>
<tr>
<td><strong>Puget Sound Study</strong></td>
<td>Vehicles were charged per mile driven, facility type and time of day</td>
<td>Cellular transmission</td>
<td>On-board unit with GPS capability. Communicates directly with central processing center</td>
<td>No invoicing, this was a study only</td>
<td>Volunteers were given a pre-paid account from which tolls were deducted</td>
<td>In-vehicle GPS unit determines location of vehicle and number of miles traveled</td>
</tr>
<tr>
<td><strong>Iowa Pooled Fund</strong></td>
<td>Vehicles charged per mile based on large geographic areas, i.e. state/county boundaries</td>
<td>Cellular transmission</td>
<td>On-board computer integrated with GPS system. Route and time data not stored</td>
<td>Billed monthly from an operations center, similar to credit card billing</td>
<td>Monthly basis; could be credit, debit or any number of payment methods</td>
<td>In-vehicle GPS unit determines location of vehicle and number of miles traveled</td>
</tr>
<tr>
<td><strong>Minnesota Pay As You Drive</strong></td>
<td>Yes, from device on OBD-II port</td>
<td>Manually downloaded from device</td>
<td>Local to the device</td>
<td>No invoicing, this was a study only</td>
<td>Collections not part of the study</td>
<td>No location data</td>
</tr>
<tr>
<td>STUDY</td>
<td>Distance Metering</td>
<td>Communications</td>
<td>Data Processing</td>
<td>Invoicing</td>
<td>Collections</td>
<td>Vehicle Locating</td>
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<tr>
<td>Germany Truck Program</td>
<td>Commercial vehicles charged per mile and per vehicle classification on Autobahn. Segment-based fee structure</td>
<td>Satellite-based with GSM connection to fee processing center</td>
<td>On-board unit with GPS capability. Communicates with roadside sensors</td>
<td>None, driver is automatically billed or manually pre-pays</td>
<td>Drivers can use manual pay-as-you-go systems or automatic payments via GPS system</td>
<td>In-vehicle GPS unit determines location of vehicle and number of miles traveled</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Vehicles charged per kilometer driven</td>
<td>Unknown at this time. Project has been postponed as of 03/09</td>
<td></td>
<td></td>
<td>Planning to have GPS-based system to determine vehicle locations</td>
<td></td>
</tr>
<tr>
<td>London Cordon Pricing</td>
<td>None</td>
<td>RF communications between vehicle and gantry systems</td>
<td>On-board units with smart card technology</td>
<td>Drivers identified by license plate and charged if in violation. Users pay by phone, internet etc.</td>
<td>Pre-pay (weekly, monthly, yearly) and post-pay system tied to on-board unit</td>
<td>None</td>
</tr>
<tr>
<td>Stockholm Cordon Pricing</td>
<td>None</td>
<td>RF communications between vehicle and gantry systems</td>
<td>On-board transponders</td>
<td>None, driver is automatically billed</td>
<td>Automatic deductions from authorized account</td>
<td>None</td>
</tr>
<tr>
<td>Singapore Area License Scheme</td>
<td>None</td>
<td>None</td>
<td>Manual checking on geographic zone boundaries</td>
<td>None</td>
<td>Pre-pay paper license</td>
<td>None</td>
</tr>
</tbody>
</table>
References


Sorensen P. A. & Taylor, B. D. (2006). Innovations in Road Finance: Examining the Growth in Electronic Tolling. *Public Works Management Policy* 11: 110-125. The online version of this article can be found at: [http://pwm.sagepub.com/cgi/content/abstract/11/2/110](http://pwm.sagepub.com/cgi/content/abstract/11/2/110)


APPENDIX B – DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

The following table provides the definitions of all terms, acronyms, and abbreviations required to properly interpret this Concept of Operations.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>511</td>
<td>A three digit telephone number for traffic information</td>
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<tr>
<td>ACS</td>
<td>Affiliated Computer Services, Inc.</td>
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<tr>
<td>ATV</td>
<td>All Terrain Vehicle</td>
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<td>AVL</td>
<td>Automatic Vehicle Location</td>
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<tr>
<td>CICAS-SSA</td>
<td>Cooperative Intersection Collision Avoidance System for Stop Sign Assist</td>
</tr>
<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
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<tr>
<td>COTS</td>
<td>Commercial Off-the-Shelf</td>
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<tr>
<td>DOT</td>
<td>Department of Transportation</td>
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<td>DPS</td>
<td>Department of Public Safety</td>
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<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communications</td>
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<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>GHz</td>
<td>Gigahertz – one billion (1,000,000,000) Hertz</td>
</tr>
<tr>
<td>GM</td>
<td>General Motors</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile communications</td>
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<tr>
<td>HOT</td>
<td>High Occupancy Toll</td>
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<tr>
<td>IFTA</td>
<td>International Fuel Tax Agreement</td>
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<tr>
<td>ISTEA</td>
<td>Intermodal Surface Transportation Efficiency Act</td>
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<tr>
<td>IVI</td>
<td>Intelligent Vehicle Initiative</td>
</tr>
<tr>
<td>IWS</td>
<td>Intersection Warning Systems</td>
</tr>
<tr>
<td>MBUF</td>
<td>Mileage-Based User Fees</td>
</tr>
<tr>
<td>MHz</td>
<td>Megahertz – one million (1,000,000) Hertz</td>
</tr>
<tr>
<td>Mn/DOT</td>
<td>Minnesota Department of Transportation</td>
</tr>
<tr>
<td>MnPASS</td>
<td>A system that allows single occupant vehicles to use a high occupancy toll lane during peak periods by paying an electronic toll</td>
</tr>
<tr>
<td>MVST</td>
<td>Motor Vehicle Sales Tax</td>
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<tr>
<td>OBD-II</td>
<td>On-Board Diagnostic</td>
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<tr>
<td>OBE</td>
<td>On-Board Equipment</td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
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<tr>
<td>PCE</td>
<td>Passenger Car Equivalent</td>
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<td>PDA</td>
<td>Personal Digital Assistant</td>
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<tr>
<td>PDSL</td>
<td>Priced Dynamic Shoulder Lanes</td>
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<tr>
<td>PND</td>
<td>Personal Navigation Device</td>
</tr>
<tr>
<td>POS</td>
<td>Point-of-Sale</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<tr>
<td>Term</td>
<td>Definition</td>
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<td>------------------------------------------------</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
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<tr>
<td>RFP</td>
<td>Request for Proposal</td>
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<tr>
<td>RSE</td>
<td>Roadside Equipment</td>
</tr>
<tr>
<td>RSU</td>
<td>Roadside Unit</td>
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<tr>
<td>RTMC</td>
<td>Regional Traffic Management Center</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
</tr>
<tr>
<td>TEA-21</td>
<td>Transportation Equity Act of the 21st Century</td>
</tr>
<tr>
<td>U.S. DOT</td>
<td>United States Department of Transportation</td>
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<tr>
<td>VII</td>
<td>Vehicle Infrastructure Integration</td>
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<tr>
<td>VMT</td>
<td>Vehicle Miles Traveled</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
</tbody>
</table>
APPENDIX C – REFERENCES


Minnesota Constitution, article XIV.


Minnesota Statute § 163.051

Minnesota Statute § 168.013, subd. 1a.

Minnesota Statute § 296A.18.

Minnesota Statute § 297B.02

Minnesota Statute § 297B.09


