DATA TRANSMISSION OPTIONS FOR VMT DATA AND FEE COLLECTION CENTERS

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16. Abstract

The Oregon Road User Fee Task Force (RUFTF) is charged with developing a design for revenue collection for Oregon's roads and highways that will replace the current system for revenue collection for all light vehicles in the state. One option under consideration is the collection of fees for vehicle miles traveled (VMT). The objectives of this report are to analyze data transmission options and provide cost estimates for VMT data and fee collection centers. This includes development of frameworks and cost estimates for mileage-based fee collection centers, including the identification of issues related to data transmission, data collection, fee collection, data processing, billing, and payment, including pre-payment options. Trade-offs have been identified and the issues related to the trade-offs have been addressed. A companion study entitled Institutional Options for VMT Data and Fee Collection Centers has examined issues related to public/private operation of fee collection centers.

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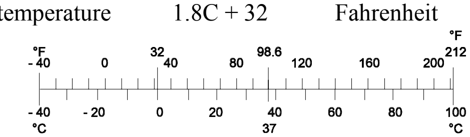
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celsius temperature	1.8C + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement (4-7-94 jbp)

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DATA TRANSMISSION OPTIONS FOR VMT DATA AND FEE COLLECTION CENTERS

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EXECUTIVE SUMMARY

The Oregon Road User Fee Task Force (RUFTF) is charged with developing a design for revenue collection for Oregon's roads and highways to replace the current system for revenue collection for all light vehicles in the state. One option under consideration is the collection of fees for vehicle miles traveled (VMT). The objectives of this report are to analyze data transmission options and provide cost estimates for VMT data and fee collection centers. This includes development of frameworks and cost estimates for mileage-based fee collection centers, including the identification of issues related to data transmission, data collection, fee collection, data processing, billing, and payment, including pre-payment options. Trade-offs have been identified and the issues related to the trade-offs have been addressed.

OVERVIEW OF SCENARIOS

A total of six scenarios are being considered for the collection and transmission of VMT data. The three scenarios that include a data and fee collection center are summarized below.

VMT Fee Scenarios

Scenario and Option	Vehicle Device and Communication System	Intermediate Hub	VMT Calculation
Scenario 1: Fee Collection Center Scenario			
Technology Option 1	GPS & Cellular Option	None	VMT calculated on-board or at data and fee collection center
Technology Option 2	GPS & RF-AVI Option	Service stations	VMT calculated on-board, at service station or at data/ fee collection center
Technology Option 3	Odometer & RF-AVI Option	Border crossings and service stations	VMT directly from odometer readings
Scenario 5: DMV/Other Public Collection Center Scenario			
Technology Option 2	GPS & RF-AVI Option	DMV/Other	VMT calculated on-board, DMV or other public collection center or at data and fee collection center
Technology Option 3	Odometer & RF-AVI Option	Border crossings and DMV/Other	VMT directly from odometer readings
Scenario 6: System-wide Spot Tolling Scenario			
	RF-AVI Option	RF readers at border crossings and on highway network	VMT approximated from tag readings on highway network

These scenarios require all vehicles to communicate directly with the data and fee collection center or communicate via an intermediate "hub." In data communications, a hub is a place of convergence where data arrives from one or more directions and is forwarded out in one or more other directions. Only Scenario 1, Technology Option 1 requires each vehicle to communicate directly with the data and fee collection center. This option would require vehicles to be equipped with an on-board global positioning system (GPS) along with a cellular communication device. It is possible that each vehicle would need to transmit its location to the data and fee collection center on a frequent basis. If the VMT were calculated on-board, the vehicle would only transmit its VMT to the data and fee collection center at some prescribed frequency.

The remaining alternatives use an intermediate data receiving/processing hub for consolidating data from many vehicles, reducing the communications requirements. Scenario 1, Option 2 uses privately owned service stations as intermediate hubs, and Scenario 1, Option 3 uses a combination of service stations and border crossings as intermediate hubs. Scenario 5 uses Driver and Motor Vehicles (DMV) Division facilities as intermediate hubs that would communicate with the data and fee collection center. Scenario 6 would place a large number of radio frequency (RF) tag readers throughout the highway network, which would act as intermediate hubs, collecting individual vehicle data and then communicating with the data and fee collection center. Communication would need to be accomplished through a variety of means (fiber optics, leased phone line, cellular, etc.) depending on local utility availability at each particular RF reader site.

If the statewide VMT fee system were designed with a constant statewide mileage fee, the calculations performed either on-board the vehicle, at the data hubs or at the service center would not need to monitor where a vehicle was traveling. If a form of variable pricing were applied in a particular corridor or cordon, then additional calculations would need to be performed either on the vehicle, at the data hub or at the service center. The definition of the corridor or cordon would not require substantially different quantities of data transmission, and thus cost estimates in later sections would be applicable for both fixed and variable pricing systems.

DATA TRANSMISSION OPTIONS

Two major data transmission options will be considered for the data and fee collection center—Wide Area and Data Hub alternatives, as described below.

Wide Area Option

Under this system, each Oregon light vehicle would contain a GPS receiver and a cellular communication unit. With off-board processing, vehicles would periodically transmit a stream of location information (i.e., the vehicle's location at specific times) for processing into a VMT summary at the data and fee collection center. With an on-board processing unit, the vehicle would periodically transmit a VMT summary to the data and fee collection center based on GPS locations determined in the vehicle. The center could be located almost anywhere in the state.

In addition to the data and fee collection center, additional customer service centers would be needed, possibly at some appropriate public facilities such as the Driver and Motor Vehicles

(DMV) Division. Customer service can be handled in person, by mail, via telephone, Internet, etc. The DMV reports that despite various options for performing transactions by mail and other means, approximately 50% of its transactions are conducted in the field offices. This indicates that some person-to-person contact will be necessary. With the wide area system, a single facility can be envisioned. Redundancy could be developed within the same facility (in case of computer error or power outage) and/or at a separate site (in case of disaster).

Data Hub Option

Under this system, individual vehicles communicate with some type of an intermediate hub, which then passes aggregated data on to the center. This concept obviates the need for every vehicle to communicate directly with the center and thus distributes and simplifies the communications infrastructure needed. A hub could be a service station, a DMV facility or an AVI tag reader located on the highway network. Under most scenarios the VMT would be calculated "upstream" of or at the hub. However with Scenario 1, Technology Option 2, vehicles would up-load raw location data at the hub and the VMT would be calculated at the center. Communication of aggregated location or VMT data from the hubs to the service center would reduce the number of transactions, the capital cost of communications equipment at the center and reduce or eliminate the communications airtime cost. Scenario 6 would aggregate the individual vehicle VMT data at the roadside AVI tag readers.

As in the wide area alternative, additional numbers of customer service centers are envisaged throughout the state, possibly at DMV or other public facilities convenient to drivers. Using the data hub model, there are possibilities for accomplishing redundancy while economizing somewhat on equipment costs. For example, if the data and fee collection center were split into four divisions at four separate locations, then if one of the divisions failed, there would still be three divisions operational. This would help ensure continuity of service and revenue stream.

DATA AND FEE COLLECTION CENTER OPTIONS

The data and fee collection facility would be similar under both main alternative systems described above, except for hardware and software differences related to handling different communication volumes. Three center alternatives were considered—first, a wide area system which requires determination of VMT at the center itself; second a wide area system wherein the VMT is calculated on-board the vehicles; and third, a data hub option where the VMT is calculated on-board the vehicles or at a hub (service station, DMV or field location of an RF tag reader). The third option included the possibility that either raw location data or calculated VMT data would be up-loaded to the hub for passage to the data and fee collection center.

Data and Fee Collection Center Cost Estimates

Capital (initial) and annual operations costs were estimated for the three fee collection center scenarios. The estimates are applicable for fixed VMT fees (applied on a statewide basis). These would also be valid and for situations where variable pricing were applied on particular corridors or within particular cordon areas. The estimates were developed assuming that approximately 3 million vehicles traveling on Oregon's roads will be paying fees. The system envisioned here would be approximately revenue neutral, recovering an estimated $390 million a year in road user fees.

Further, real-world operating costs from the SmartTag service center in Virginia for year 2002 were used as reference in generating operations estimates for the data and fee collection center. During implementation, customer service decisions would need to be made. It has been assumed that satellite customer service centers would be located in or near existing DMV offices. This does not imply that this is actually physically feasible, since existing DMV facilities may be operating at capacity.

Data and Fee Collection Cost Estimates

	Wide Area Location Data ($M)	Wide Area VMT Data ($M)	Service Station or DMV Hub ($M)
CAPITAL COSTS			
Subtotal Capital Costs	3.00-5.52	0.78	0.70
Contingency (20%)	0.60-1.10	0.16	0.14
TOTAL CAPITAL COSTS	3.6-6.6	0.94	0.84
ANNUAL COSTS			
Subtotal Annual Costs	92.9-96.2	42.5-45.3	39.4-42.2
Contingency (20%)	18.6-19.2	8.5-9.1	7.9-8.4
TOTAL ANNUAL COSTS	111.5-115.4	51.0-54.4	47.5-50.6

DATA TRANSMISSION OPTIONS SUMMARY

In summary, there are two options for setting up fee collection centers--wide area and data hub. In the wide area option, either calculated VMT or raw location data is transmitted from the vehicle to collection centers using cellular communications. Data is transmitted from the vehicle to the center at frequent intervals (e.g., daily or monthly). In the data hub option, calculated VMT or raw location data is transmitted from the vehicle to an intermediary reader located at DMVs or fuel stations.

In either data transmission option, vehicle data may be processed at centralized or distributed centers. The centralized configuration assumes that one data center is responsible for the collection of all VMT or raw location data. The distributed center option allows for vehicle data to be sent to a number of centers for processing. Transmission may be accomplished via cellular (directly from vehicle to center) or RF (from vehicle to hub). Landline communication is required to transfer data from RF hubs to centers. Landline communications may also be used for communications between service centers.

Fees calculated from the processed VMT data may occur through billing cycles or direct payment at hubs. User fees processed via billing cycles is the only system for the wide area option. Statement generation may be based on the VMT calculated for a certain time interval and road users are sent a periodic statement. Billing cycles may also be appropriate for data hubs co-located at DMVs. These statements would be generated in a manner similar to the wide area option. An alternative payment approach for data hubs may occur on a per transaction basis whereby road users pay the appropriate fee at the fuel station. In the technology options where complete direct payment occurs at the hubs, then the data center would not be necessary.

For both wide area and data hub transmission options, the same customer service needs exist. Walk-in customer service may be required for those accustomed to paying for service with cash, especially if VMT fees are processed on a monthly basis. The walk-in service center could also provide other services such as reconciling accounts, answering questions, and performing functions similar to servicing DMV patrons. Another type of customer service center is one that does not provide customer service support and manages the processing of data and bill generation. Support is provided electronically, for example, through telephone or the Internet. The following table summarizes considerations for the various component options for establishing fee collection centers:

Configuration Options

System Options	**Considerations**
Wide Area	▪ Requires reliable and secure cellular network. ▪ Greater user convenience as data transmission is seamless.
Data Hub	▪ May be inconvenient for users to visit hubs located at DMVs more than once a year.
Center Options	
Centralized	▪ Need to establish back up system to address disaster recovery. ▪ Necessary back up system may be costly, but required. ▪ Back up system inactivity may result in unstable operating environment.
Distributed	▪ Greater capital and operating costs. ▪ Multiple processing points allow for back up system to exist within network.
Data Transmission	
Cellular	▪ Airtime charges for frequent data transmission may prove cost prohibitive.
RF/Landline	▪ Requires road user to be within a certain data frequency range data hub to upload data. ▪ Cheaper alternative as landline charges are independent of frequency of data transmissions.
Customer Service and Support Needs	
Walk-In Service	▪ Need to consider multiple methods of payment to ensure user convenience. ▪ Provides support to greater number of road users.
No Walk-In Service	▪ Lack of options for road users wanting in-person assistance. ▪ Requires less staff to operate service centers.
Billing Options	
Statement Generation Frequency	▪ Frequency of billing affects operations costs associated with statement generation, postage, handling, and materials cost. ▪ Infrequent billing cycles will not allow the state to recoup fees at regular intervals to support programs.
Payment Options	▪ Cash payment requires walk-in service support and extra staffing at service centers. ▪ Credit card transaction costs range from 2.5 to 3.75 percent of charges.

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

The Oregon Road User Fee Task Force (RUFTF) is charged with developing a design for revenue collection for Oregon's roads and highways that will replace the current system for revenue collection for all light vehicles in the state. The Task Force has issued a set of problem statements that call for development of additional information to assist the Task Force. This report documents the results of a research project aimed at providing responses to one of these questions related to a data and fee collection center.

Some potential new systems of revenue collection would depend upon a functioning data and fee collection center. Outside of the transportation field, such centers are common (e.g., the data processing and billing activities of telecommunications firms).

In the transportation field, data and fee collection centers exist to serve automatic vehicle identification (AVI) based toll systems on limited access highways. However, suggested new systems of revenue collection involve data collection from in-vehicle databases, statewide applicability (not just a specific highway segment), and collection from all light vehicle owners in the state.

In order to evaluate the viability of new systems of revenue collection based upon a data and fee collection center, the Oregon Department of Transportation (ODOT) needs to understand the data transmission options and choices that must be made to determine major subsystems, and their cost implications.

1.2 BACKGROUND

During the 2001 regular session of the Oregon Legislature, the Legislative Assembly approved House Bill 3946. This bill created the Road User Fee Task Force (RUFTF). *The purpose of the Task Force is to develop a design for revenue collection for Oregon's roads and highways that will replace the current system for revenue collection.* The primary concern of the Legislature is that fuel taxes are becoming a less effective mechanism for meeting long-term highway revenue needs.

This concern stems from two sources. One is the perception that fuel taxpayers do not understand the linkage between the amounts they pay and their use of roads and highways. The other is that fuel taxes will generate less revenue as vehicles become more fuel efficient, particularly with the advent of hybrid-electric and fuel cell vehicles.

Finally, House Bill 3946 requires the Oregon Department of Transportation (ODOT) to begin implementation of pilot programs by July 1, 2003. The pilot programs are to be designed to test alternatives to the current system of taxing highway use through fuel taxes.

In 1995, National Cooperative Highway Research Program (NCHRP) Report 377, *Alternatives to Motor Fuel Taxes for Financing Surface Transportation Improvements* was published (*Reno 1995*). This report identified and evaluated alternatives to the traditional fuel tax. The report concluded that a desirable replacement for motor fuel taxes would be a fee or tax based on vehicle miles traveled (VMT). It also concluded that fuel tax revenue would continue to be an important revenue source for surface transportation programs well into the future – for at least the next three decades.

Since the research was completed for NCHRP 377, major breakthroughs in automotive technology have occurred (e.g., hybrid-electric vehicles, compressed natural gas vehicles, fuel cell vehicles). These breakthroughs have come about sooner than expected. The Partnership for a New Generation of Vehicles (PNGV) has made substantial progress in reaching its goal to develop 80 mpg midsize cars by around 2005 without sacrificing affordability, performance or safety. Consequently, revenues from fuel taxes may decline sooner than projected in the NCHRP report, and one or more alternative approaches for financing the highway transportation system will need to be developed. In addition, a variety of projects have been funded by the Federal Highway Administration (FHWA) Value Pricing Pilot Program to test various pricing approaches, and there have been significant improvements in the technology for implementing automated pricing systems.

In early 2001, ODOT funded a research project designed to build on NCHRP 377 and consider what has been learned since the NCHRP report was published. This report is titled, Alternatives to the Motor Fuel Tax, and was published in December 2001. The report identifies issues, provides an overview of various potential fee collection technologies, and draws many relevant conclusions.

The Minnesota Department of Transportation is coordinating a project titled, *A New Approach to Assessing Road User Charges*. The project is financed by a group of states that have combined together (or "pooled") relatively small amounts of federal transportation research funds. Oregon is a participant in this pooled fund study.

1.3 OBJECTIVES

The objectives of this report are to analyze data transmission options and provide cost estimates for data and fee collection centers. This includes development of frameworks and cost estimates for mileage-based fee collection centers, including the identification of issues related to data transmission, data collection, fee collection, data processing, billing, and payment, including pre-payment options. Trade-offs have been identified and the issues related to the trade-offs have been addressed as fully as possible within the scope of the project. A companion study entitled *Institutional Options for VMT Data and Fee Collection Centers* is examining issues related to public/private operation of fee collection centers.

1.4 OVERVIEW OF SCENARIOS

At present, under the auspices of a separate study (*Kim, et al. 2002*), a total of six scenarios are being considered for the collection and transmission of vehicle miles traveled (VMT) data in the state of Oregon. These data will be used as a basis for charging the appropriate VMT fee, either directly or with a credit reduction for gas tax paid. The scenarios are summarized in Table 1.1 below. The second column in the table describes the basic type of in-vehicle device proposed and the third column summarizes the type of communication system used to transfer data out of the vehicle. The fourth column indicates whether there is an intermediate hub proposed between the vehicles and the data and fee collection center, and the fifth and final column summarizes the method(s) used for calculating the VMT and/or VMT fee.

Table 1.1: VMT Fee Scenarios

Scenario and Option	Vehicle Device and Communication System	Intermediate Hub	VMT Calculation
Scenario 1: Fee Collection Center Scenario			
Technology Option 1	GPS & Cellular Option	None	VMT calculated on-board or at data and fee collection center.
Technology Option 2	GPS & RF-AVI Option	Service stations	VMT calculated on-board, at service station or at data and fee collection center.
Technology Option 3	Odometer & RF-AVI Option	Border crossings and service stations	VMT directly from odometer readings.
Scenario 2: Actual VMT @ Pump with Credit Scenario (no data and fee collection center)			
Technology Option 2	GPS & RF-AVI Option	Service stations	VMT calculated on-board or at service station and fee added to purchase price.
Technology Option 3	Odometer & RF-AVI Option	Border crossings and service stations	VMT directly from odometer readings and fee added to purchase price.
Scenario 3: Actual VMT @ Pump with Switch Scenario (no data and fee collection center)			
Technology Option 2	GPS & RF-AVI Option	Service stations	VMT calculated on-board or at service station, gas tax turned off, actual fee charged
Technology Option 3	Odometer & RF-AVI Option	Border crossings and service stations	VMT directly from odometer readings, gas tax turned off, actual fee charged.
Scenario 4: Estimated VMT @ Pump with Credit Estimate Scenario (no data and fee collection center)			
	RF-AVI with EPA Data Option	Service stations	VMT estimated from EPA data, additional VMT fee added to purchase price
Scenario 5: DMV/Other Public Collection Center Scenario			
Technology Option 2	GPS & RF-AVI Option	DMV/Other	VMT calculated on-board, DMV or other public collection center or at data and fee collection center.
Technology Option 3	Odometer & RF-AVI Option	Border crossings and DMV/Other	VMT directly from odometer readings.
Scenario 6: System-wide Spot Tolling Scenario			
	RF-AVI Option	RF Readers at border crossings and on highway network	VMT approximated from tag readings on highway network

The scenarios described above either describe systems that require all vehicles to communicate directly with the data and fee collection center or accomplish this communication via an intermediate "hub" of some sort. In data communications, a hub is a place of convergence where data arrives from one or more directions and is forwarded out in one or more other directions. As shown in Table 1, only Scenario 1, Technology Option 1 proposes to use a system where each vehicle communicates directly with the data and fee collection center. This option would require vehicles to be equipped with an on-board global positioning system (GPS) along with a cellular communication device. It is possible that each vehicle would need to transmit its location to the data and fee collection center on a periodic basis. In a sense, this could be conceived as the "worst case" in terms of data transmission requirements. On the other hand, if the VMT could be calculated on-board, the vehicle would only need to transmit its VMT to the data and fee collection center at some prescribed frequency.

The remaining alternatives use some type of intermediate data receiving/processing hub for consolidating data from many vehicles. This reduces the communications requirements. Scenario 1, Option 2 uses privately owned service stations as intermediate hubs, and Scenario 1, Option 3 uses a combination of service stations and border crossings as intermediate hubs. In the case of Scenarios 2, 3 and 4, the data and fee collection would take place entirely at service stations, so no additional data would be passed along from the service station. Scenario 5 uses Driver and Motor Vehicles (DMV) Division facilities as intermediate hubs that would communicate with the data and fee collection center. Scenario 6 would place a large number of radio frequency (RF) tag readers throughout the highway network, which would act as intermediate hubs, collecting individual vehicle data and then communicating with the data and fee collection center. The communication would need to be accomplished through a variety of means (fiber optics, leased phone line, cellular, etc.) depending on local utility availability at each particular RF reader site.

If the statewide VMT fee system were designed with a constant statewide mileage fee, the calculations performed either on-board the vehicle, at the data hubs or at the service center would not need to keep track of where a vehicle was traveling. If some form of variable pricing were applied in a particular corridor or within a particular cordon, then additional calculations would need to be performed either on the vehicle, at the data hub or at the service center. The definition of the corridor or cordon would not require substantially different quantities of data transmission, and thus cost estimates in later sections would be applicable for both fixed and variable pricing systems.

1.5 DATA TRANSMISSION OPTIONS

Given the array of in-vehicle and communications technologies described above, it will be important to consider the associated data and fee collection center requirements and issues connected with each option. As a means of focusing the analysis, two major data transmission options will be considered for the data and fee collection center—Wide Area and Data Hub alternatives, as described below.

1.5.1 Wide Area Option

This concept for the data and fee collection center consists of a system wherein each Oregon light vehicle would contain a GPS receiver and a cellular communication unit. With off-board processing, vehicles would periodically transmit a stream of location information (i.e., the vehicle's location at specific times) for processing into a VMT summary at the data and fee collection center. Alternatively, with an on-board processing unit, the vehicle would merely periodically transmit a VMT summary to the data and fee collection center based on GPS locations determined on the in-vehicle unit. The center itself could be physically located almost anywhere in the state.

In addition to the data and fee collection center, it would be likely that additional customer service centers would be needed throughout the state, possibly at some appropriate public facilities. The Driver and Motor Vehicles (DMV) Division has been identified as one such customer service partner, since its 68 facilities are located so that 95% of the state's population lives within 30 miles of a DMV office. The issue of how and where to handle customer service is a significant implementation issue. Customer service can be handled in person, by mail, via telephone (using toll free numbers and automated voice responsive systems), Internet, etc. The DMV reports that despite various options for performing transactions by mail and other means, approximately 50% of its transactions are conducted in the field offices. This indicates that some person-to-person contact will be necessary.

With the wide area system, a single facility can be envisioned, with needs for redundancy. Such redundancy could be developed within the same facility (in case of computer error or power outage) and/or at a separate site (in case of natural disaster).

1.5.2 Data Hub Option

The second concept for the data and fee collection center is one in which individual vehicles communicate with some type of an intermediate hub (as defined above), which then passes aggregated data on to the center. This concept obviates the need for every vehicle to communicate directly with the center and thus distributes and simplifies the communications infrastructure needed at the center. As noted above, a hub could be a service station, a DMV facility or an AVI tag reader located on the highway network. Under most scenarios the VMT would be calculated "upstream" of or at the hub; however Scenario 1, Technology Option 2 includes the possibility that vehicles would up-load raw location data at the hub and that the VMT would be calculated at the service center. Communication of aggregated location or VMT data from the hubs to the service center would substantially reduce the number of transactions, reducing the capital cost of communications equipment at the center and reducing or eliminating the airtime cost of communications as well. Scenario 6 would aggregate the individual vehicle VMT data at the roadside AVI tag readers, which would also reduce the communications requirements.

As in the wide area alternative, additional numbers of customer service centers are envisioned throughout the state, possibly at DMV or other public facilities convenient to drivers. Using the data hub model, there are possibilities for accomplishing redundancy while economizing somewhat on equipment costs. For example, if the data and fee collection center were split into four pieces at four separate locations, then if one of the pieces failed, there would still be three segments operational. This would help ensure continuity of service and revenue stream.

1.6 DATA AND FEE COLLECTION CENTER OPTIONS

The data and fee collection facility would be similar under both main alternative systems described above, except for hardware and software differences related to handling vastly different magnitudes of communication events. These differences will be described below. Three main center alternatives will be considered—first, a wide area system which requires determination of VMT at the center itself; second a wide area system wherein the VMT is calculated on-board the vehicles; and third, a data hub option where the VMT is calculated on-board the vehicles or at a hub (service station, DMV or field location of an RF tag reader). The third option includes the possibility that either raw location data or calculated VMT data would be up-loaded to the hub for passage to the data and fee collection center.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The data and fee collection center will manage a number of functions including receiving VMT data collected from up-loading facilities, maintaining records of all transactions, maintaining vehicle accounts, and providing a mechanism for payment and sending late notices (*Forkenbrock 2001*). The data and fee collection center would be designed to handle non-payment and fee collection-related problems, but would not be conceived as the tax-enforcement body for ensuring full statewide compliance with VMT fee system. The data and fee collection requirements imply a number of technological issues for the center. Most generally, these include the transmission of data from the on-board VMT recording device to the data center and the processing of data at the center. Procedures for developing bills, processing payments from drivers and other customer service requirements are also of interest.

While an exact model for this kind of center does not currently exist, both transportation management centers (TMCs) and electronic toll collection (ETC) facilities have comparable functions. Some experiences of transit agencies also serve as useful guides.

2.2 DATA TRANSMISSION

Transmission of data from the on-board VMT device to the data center requires a mechanism for providing reliable and secure communication. Designers of transportation management centers have also noted the importance of adequate network capacity for data transmissions in a U.S. Department of Transportation (USDOT) study (*1999*). Such data transmission is governed by standards developed by USDOT (*2002*), and that organization is in the process of developing standards for communication between transportation centers and their field equipment (*Pearce 2000*)—a relationship similar to the data center-to-vehicle relationship in the potential Oregon VMT fee system. This connection is even more valid under one of the potential scenarios consisting of intermediate hubs such as service stations, DMV facilities or highway-based RF readers.

As one author emphasizes, the choice of data transmission technology should reflect the needs of the particular project. These might include the types of data needed for the program, the effective operating ranges of the application, potential data acquisition or transmission interference, data communication requirements and life cycle costs of the technology (*Klein 2001*). The two technologies under consideration for the Oregon VMT fee are cellular and direct link (RF), mainly because of their availability and because they have proven effective in similar projects. RF transponders are used in countless electronic toll collection systems and commercial vehicle credential checking stations across the country. The Denver Regional Transportation

District and the Tri-County Metropolitan Transit District of Oregon (TriMet) are examples of agencies that use cellular communications for automatic vehicle location (AVL) systems.

Cellular communications is a promising technology and is considered successful despite its geographically limited deployment (*McGurrin 2000*). For a state like Oregon with large areas with sparse population, complete cellular coverage can be difficult to achieve. Both analog and digital systems have substantial gaps in their coverage that create areas with no service. However, a tri-mode cellular service might help fill these gaps and provide adequate coverage (*Kuhl 2001*). The Denver system uses a Time Division Multiple Access (TDMA) data/voice communication system for transmission. There are several dead spots within the service area, but additional repeaters provide adequate compensation. The system is running within specifications, with no significant number of messages being lost or delayed in transmission (*Weatherford 2000*). TriMet uses a Cellular Digital Packet Data (CDPD) system for communications between its buses, bus stops and operations center. CDPD is a data transmission technology developed for use on cellular phone frequencies. CDPD uses unused cellular channels (in the 800- to 900-MHz range) to transmit data in packets. This technology offers data transfer rates of up to 19.2 Kbps, quicker call set up, and better error correction than using modems on an analog cellular channel.

Direct link (RF) communication technology does not provide the wide coverage offered by cellular, but when used at selected receiver points it can be very reliable. Despite a lack of standardization among transponders there is increasing interoperability with this technology. RF is available in two forms: passive and active. Passive devices draw their energy from the reader, while active devices generate power from a battery or through a connection to vehicle power (*Klein 2001; FHWA 1997*). Passive RF is less expensive than active RF, but it has a lower strength signal that limits its read-range and increases the risk of electrical interference (*Klein 2001; FHWA 1997*). Active RF functions over ranges of up to 100 meters and reduces the risk of electrical interference because of its stronger signal. However, the complexity of the device makes it more expensive than the passive device, and its stronger signal means there is a greater likelihood of interference (*FHWA 1997*). With the active and passive devices, radio frequency and other radiation fields can cause interference, and the location of the tag/transponder must be controlled to guarantee communication with the reader (*ITE 2000*). This is a widely deployed technology that has largely overcome problems with data errors (*Pearce 2000*).

There is a national effort to standardize Dedicated Short Range Communications (DRSC) systems for intelligent transportation systems (ITS) applications so that devices (such as RF toll tags) from different manufacturers can be interoperable. This effort is still underway. Other wireless standards such as Bluetooth may provide a model for standardization, or may simply function as an alternative that reduces the need for DRSC technology (*McGurrin 2000*).

2.3 DATA COLLECTION

Despite the safeguards built into the latest technology, it is expected that some transmission errors will still occur. Management of these errors is a major component of data collection. The data and fee collection center should use available technology to identify and correct data errors (*Kuhl 2001*). It is also important that a procedure for correcting those errors is specified. RF transponder error is addressed with error avoidance (error detection) techniques including data integrity encoding, multiple read cycles and read-write-read again cycles (*ITE 2000*). As additional back up, heavy vehicles using transponders in the Swiss VMT fee collection system keep logbooks and paper forms (*ITS America 2001*).

Equipment malfunctioning and tampering can also cause problems for data collection. For errors resulting from equipment malfunction, escalating charges might provide incentives for customers to bring in their vehicles for servicing. The servicing may even detect tampering (*Kuhl 2001*). The Swiss employ a motion-sensor in the GPS portion of their on-board unit to detect equipment tampering (*ITS America 2001*).

Security will be an issue no matter what form of technology is employed in the data transfer. Encryption can protect the privacy of drivers and safeguard the security of the transmission by creating a digital signature with the vehicle's unique encryption key. Such protections separate the driver's personal information and other data collected for purposes other than billing, thus keeping most data received at the data center anonymous (*Abel, et al. 2001*).

2.4 DATA PROCESSING

As a data and fee collection center will receive VMT data from all Oregon vehicles while traveling in-state, and use the data to generate charges for drivers, system security and protections for personal information are of great interest.

The functions of the data and fee collection center would include receiving VMT data, preparing and distributing billing, receiving and processing payments, directing revenue to appropriate jurisdictions, and maintaining records of highway use (*Forkenbrock 2001*). In maintaining records, the center should protect the data both out of concern for system failure and for the privacy of drivers. In order to protect from system failure, a number of similar data processing centers, including Boston, Houston, and Atlanta transportation management centers, incorporate redundancy and other back-up measures into their systems (*USDOT 1999*). The ATX Technologies Telematics system has geographically dispersed on-site/off-site redundancy (*ATX Technologies 2002*). It has a master Technology Management Center (TMC) and multiple secondary technology centers. The centers utilize all-hours redundant and distributed back-up, power distribution and facilities. An individual center's networking monitoring and management are guaranteed through back up provided by the TMC (*Business Wire 2002*).

There is a growing body of literature concerning the archiving of data collected for ITS applications. Many traffic management centers archive data, but they do so on an informal basis because there is not yet an established standard (*USDOT 2000*). The data may be useful for numerous purposes including planning, design, operations, etc., but those who wish to use the data encounter limitations such as undefined database structure, poor or undefined data quality and proprietary concerns (*Texas Transportation Researcher 2001*). Those proprietary concerns have much to do with protecting the privacy of drivers from whom the agency collects data.

Seamone and Forkenbrock (*2001*) emphasize the importance of protecting driver privacy, and note that individuals have the right to an expectation of privacy concerning personal information stored on a comprehensive computerized database. Yet even though the authors find legal precedent for these protections, another source notes that state privacy laws offer only a patchwork of protections, and that not all states will have laws that adequately govern the use of private information in ITS. Individual programs should consider driver privacy and develop safeguards when considering system architecture design (*Lafrance-Linden, et al. 1995*). The Intelligent Transportation Society of America's "Fair Information and Privacy Principles" offer a guide for incorporating such safeguards in ITS design and operations (*ITS America 2002*).

One privacy concern of drivers is how their personal information will be used once it is collected. An agency might relieve driver fears by developing a statement explaining policies on data collection and use (*Seamone and Forkenbrock 2001*). The 91 Express Lanes, an electronic toll collection system in California, posts privacy policies on their website, listing the types of data collected from drivers and explaining how the data are used and under what circumstances they may be released to third parties (*91 Express Lanes 2002*)[1].

2.5 FEE COLLECTION

The ITS Electronic Payment Systems Task Force (*ITS America 2001*) describes the revenue collection functions associated with electronic toll collection. These include payment media validation, payment media collection, payment media processing (money room operations) and payment media depositing. A data and fee collection center in the Oregon project would likely take on similar functions. In addition to processing VMT data collected from vehicles, the center would generate bills and process payments from Oregon drivers.

The way in which drivers make payments could take a number of forms depending on whether individuals pay for their expected VMT in advance or if the center produces a bill for the exact VMT. Abel, et al. describe a number of billing options (*2001*). A monthly or quarterly bill would resemble a utility bill, listing the charges and stating the total amount due. "Threshold billing" is a second option, which relies on prepayment. The agency charges drivers a pre-set amount each month to cover their anticipated VMT. If the account balance falls below an acceptable threshold, the account holder's credit card is charged an additional amount. Another option would be to develop a partnership with an entity that has already established a financial relationship with Oregon drivers. For example, all drivers pay a fee to the DMV for their driver license, and all vehicle owners pay vehicle registration fees to the DMV. Further, all drivers are required by law to have insurance and thus pay insurance premiums to insurance companies. Vehicle owners who subscribe to a telematics service have established financial relationships with the automobile companies or after-market entities that offer such services. On a household basis, most Oregon households have financial relationships with electric and telephone utility companies. Another set of options involves use of a smart card. Drivers could purchase credit

[1] The office of the Oregon Attorney General addressed the issue of use of driver information in a 1998 opinion. The opinion was issued in response to questions from the Driver and Motor Vehicle Services Branch of the Oregon Department of Transportation. The opinion advised that information from motor vehicle records could be released to state agencies and other parties (the news media, for example) so long as use of the information was tied to "the gathering and dissemination of information related to the operation of a motor vehicle or to public safety." (Oregon Attorney General, 1998).

on their smart card and have their VMT fee charged to the card. Real-time billing is the final alternative; this would also use the smart card but in this form the driver's smart card would debit the amount of the charge directly from the driver's credit card, debit card, or checking account.

While it is possible to anticipate that many customers will pay with a credit card, they must also have the option to pay by more traditional methods. While 81 percent of Americans have a credit card (*Restaurants USA 2002*), 80 percent of all transactions under twenty dollars are still made with cash (*ITS America 2001*). The 91 Express Lanes provide walk-in service for customers who prefer to pay in person, but the self-service payment options available over the phone and Internet are the most popular (*Evans 2002*).

The ITS Electronic Payment Systems Task Force describes the advantages and disadvantages of various payment options from the point of view of customers as well as the agency processing payments (*ITS America 2001*). First, they point to universal acceptance as the major benefit of cash payments. There are substantial disadvantages on the payee side, however. There is a high cost associated with handling and processing cash, and the risk of theft and loss is high. Cash can cause problems administratively as well, as it can complicate payment tracking and accountability. Checks, travelers' checks and money orders are the second category of payment. Use of these alternatives can reduce the risk of theft and loss and facilitate accountability and tracking. The disadvantage is that the acceptor takes the risk of issue default with these options. Also, they come with lower security requirements, which increase the risk of counterfeit and fraud. Finally, the task force identifies credit cards as providing the simplest form of revenue collection for the payment acceptor. This form eliminates some security concerns, reduces the risk of theft and fraud, and is often preferred by customers. The main disadvantage is the cost of transaction fees, which may be as high as 2.5 to 3.75 percent (*Castle Rock 2001*) of the transaction charges. There can also be compatibility problems--customers need to have the right credit card.

2.6 SMART CARDS

A smart card is a plastic card about the size of a credit card, with an embedded microchip that can be loaded with data, used for telephone calling, electronic cash payments, and other applications, and then periodically refreshed for additional use. Smart cards have the potential for playing a role in a statewide VMT fee system, either as a permanent solution or during a transition phase (*Kuhn 2002*). Over a billion smart cards are already in use, primarily in Europe. The microprocessor embedded in smart cards moves the technology beyond the abilities of magnetic strip cards and allows many transactions that are personal to the user. The card can hold far more data than a conventional magnetic stripe card and it communicates digitally to perform numerous transactions and activities. Smart card costs are declining and most smart cards contain 32k of memory, although more expensive versions with 64k and 128k are also available (*Briney 2002*).

Increasingly, transit agencies and electronic toll collection facilities employ smart cards. Smart cards are advantageous for transit companies because they are expected to be more reliable than magnetic stripes, they have a greater capacity for data collection and processing, and trends toward smart card use by other industries offer the potential for joint arrangements (*Andrle 1997*). For example, in the San Francisco Bay Area, a pilot project is testing the use of smart cards for a multi-agency transit fare payment system. Pearce, in his study of electronic toll facilities, found that the technology has been successfully deployed, but is limited by acceptance of users and by the need for industry standards (*2000*). Security is also a problem with the technology, but newer products are addressing this issue (*Briney 2002*).

Interoperability is a main limitation of the smart card technology. Major credit card companies, including Visa, American Express, Discover, and MasterCard have developed smart cards, but none of the platforms is compatible with any of the others and installation of the infrastructure necessary for vendors to accept the cards would cost them nearly $8 billion (*Briney 2002*). There is not currently a model for fee agreements on smart cards. Individual transit agencies have reached their own agreements with financial institutions (*Andrle 1997*).

2.6.1 Smart Card Administrative Requirements

In a survey of transit agency practice regarding sales of new cards it was shown that many agencies sell cards through personnel at transit stations (8); but Internet and vending machines (4), mail order (3), and merchant contracts (2) were also cited (*Healy and Kapilian 2001*). The same study found that five transit agencies used staff to respond to customer concerns regarding smart card or equipment failure while three used contractors (*Healy and Kapilian 2001*).

In addition, a review of cost categories associated with smart cards revealed the following components:

- Procurement and installation of fare collection and dispensing equipment
- Procurement and installation of computer system
- Installation or modification of communications infrastructure and system
- Purchase or production of fare media
- Day-to-day administration
- Maintenance and repair
- Marketing
- Sales and distribution
- Revenue accounting
- Training of staff (maintenance, operations, customer service, revenue, finance) (*Andrle 1997*).

The author adds that the chief cost of a smart card program for a transit agency might be the transaction fee per use that is paid to the system operator or card issuer. The transaction agreement between the agency and financial institution will be key to ensuring that the partnership is beneficial for both parties (*Andrle 1997*). Andrle also notes that if a private entity were managing the system, some of the above costs may be covered by transaction fees and loss of revenue currently received from “float” (from prepaid media sales) and unused value (from stored-value media).

2.6.2 State of the Industry

While most credit card companies have smart cards, a few examples stand out. American Express' recent experiment with their Blue Chip smart card was a failure despite the company's offer of 500,000 free card readers for first time customers. There are fewer that 5 million Blue Chip cardholders and it is believed that far fewer cards are used (*Briney 2002*). Yet companies continue to develop the technology. Davis and Balaban (*2002*) describe a number of recent advancements. FeliCa, the Sony Corporation's contactless smart card, uses a radio-frequency interface and is used for transit fare payments. Citibank released a U.S. smart card in 2002. Finally, in apparent expectation of increasing use by customers, Target stores will convert 37,000 terminals at over 900 stores to accept smart cards.

2.6.3 Future

Since smart cards are an emerging technology, authors are still asking questions as simple as "who will purchase the smart card?" (*Andrle 1997*). The future of smart cards will depend in large part on advances in interoperability. For example, the lack of feasible reader-technology is a barrier for smart cards. Retailers, transit agencies, and other end-users need a device that is easy to use and affordable (*Briney 2002*).

Advances in smart card interoperability will in turn depend on their use in other industries. As the ITS Electronic Payment Systems Task Force notes, the low transaction values usually generated by transportation services are generally not attractive to financial institutions. Transportation agencies might find banks to be good partners if they can see smart card programs as a way to attract additional customers (*ITS America 2001*). The appeal of smart cards to customers will depend on the ease of their use and their compatibility with other uses.

3.0 DATA TRANSMISSION OPTIONS AND COST ESTIMATES FOR DATA AND FEE COLLECTION CENTER

3.1 INTRODUCTION

This section describes data transmission options and cost estimates for the proposed data and fee collection center.

3.2 ISSUES

There are numerous issues to be synthesized, including the means of transmitting data from the vehicles or hubs to the data and fee collection center, the costs of this transmission, the required data transmission frequency and the requirements for interoperability with other systems.

3.2.1 Data Transmission

3.2.1.1 Wireless Communications

The wide area data transmission system would be based upon cellular technology. The current analog cellular network provides nearly complete coverage in Oregon, to the extent that telematics providers and other industries rely on this network for mayday systems and other life-critical communications needs. It is important to emphasize that service coverage is not 100% complete, however, particularly in sparsely populated area (and areas with unpaved roads). Kuhl (*2001*) emphasizes two problems with wireless data transmission. The first concerns service coverage. Vehicles would need to pass through access points with adequate frequency to upload data collected on-board. If the vehicle did not enter a cellular service range often enough, the data may exceed the storage capacity of the device or the upload time might be too lengthy. The second issue relates to transmission reliability. Service degradation and interruption are problems often associated with wireless communications, and there is a risk of incomplete data transmissions or duplications in data transmissions without the installation of adequate transactional system protocols.

Forecasts indicate that the cellular network will only become more widespread, more secure, more reliable and will allow higher bandwidth data transfers (i.e. web browsing and video). As an indication that the future of the cellular network is strong, Rysavy (*2001*) and Poliski (*2002*) report that operators are investing billions in third generation (3G) wireless technology that provides better transmission of high-speed data than current cellular technology, enabling more complex applications. The airtime costs of transmitting wide area location data to the service center would be quite high, so there would be trade-offs between higher cost in-vehicle devices capable of calculating VMT and the reduced communications cost of transmitting VMT summaries.

The ongoing pooled fund study led by the Minnesota Department of Transportation (*Kuhl 2002*) does not currently regard cellular technology, or other wireless communication modalities, as the most viable approach for collecting new forms of road user charges. The current rationale for setting aside wireless communication at this point in their study appears to be based on a number of factors, of which security and geographical coverage are just two.

One important consideration in the pooled fund study's findings involves the potentially long phase-in time required to implement a new approach on a national basis. Kuhl (*2002*) estimates that this phase-in time could be as long as one to two decades, during which time there would be a mix of equipped and unequipped vehicles on the road as well as both equipped and unequipped service stations. In the vision of the pooled fund study research team, during a long phase-in period, unequipped vehicles would presumably continue to pay a per-gallon gas tax while equipped vehicles would transition to a new per-mile system. This suggests that service stations would need to be able to charge for fuel with or without the addition of a per-gallon gas tax (or, alternatively, that some mechanism be employed to rebate the cost of this tax to VMT fee participants). During the phase-in time, the pooled fund study team envisions that service would become equipped with technology ("smart pumps") designed to automatically handle both equipped and non-equipped vehicles. However, the costs of this transition would be high, suggesting the need for a robust, low cost means for allowing non-equipped service stations to handle both gas tax and VMT fee users.

The pooled fund study team appears to have concluded that a transfer mechanism employing a smart card to transfer data from the vehicle would best address the constraints noted above. Other considerations included the following:

- Need for technological stability over a long phase-in period (cellular technologies tend to evolve rapidly leading to technological obsolescence of old-generation equipment).
- Lack of ubiquitous coverage by any single cellular technology--particularly in rural and remote areas.
- Costs associated with using a tariffed, commercial infrastructure for data transfer.
- Costs associated with maintaining call centers to handle connection-based cellular data uploads.
- Robustness and security considerations (*Kuhl 2002*)

While the pooled fund study conclusions are not finalized or available, the study team appears to advocate the use of simpler, more robust, and more cost effective alternatives to the use of wireless data communications for data upload in a VMT fee system, and that a smart card based approach may the most attractive at this juncture. However, the study team recognizes that it is entirely possible that future developments in wireless technology and infrastructure may alter this conclusion.

3.2.1.2 Landline Data Transmission

For a data transmission option based on a data hub, communication would be feasible via landline telephone or computer network/Internet systems that may already exist at service stations and DMV or other public facilities. These networks are less costly for communications and there are no substantial issues regarding state coverage.

3.2.2 Interoperability

A valuable array of interoperability considerations can be drawn from Virginia's investigation of integrating their SmartTag electronic toll collection (ETC) system with another ETC facility. SmartTag is currently operating in Virginia, and neighboring states and authorities provide different electronic toll collection services. The E-ZPass, one of the largest, is used to facilitate travel along the I-95 corridor that stretches along the eastern seaboard.

When the Virginia Department of Transportation (VDOT) began developing their ETC system, they initially investigated the possibility of participating in E-ZPass. At that time (1994-1995) E-ZPass was being used only in the state of New York. Since most of the Virginia roads were commuter routes, there was not sufficient traffic in common between Virginia and New York to support reciprocity.

There was concern for reciprocity within Virginia. Unlike many states, Virginia has several different toll authorities - VDOT, TRIP II, RMA, the City of Chesapeake, the Pocahontas Parkway Association and the Chesapeake Bay Bridge Tunnel Commission - quite a variety of "owners" when it comes to toll facilities. VDOT elected to design an ETC system that would serve them all—i.e., to achieve reciprocity and consistency within the Commonwealth of Virginia. To date, only one toll facility in Virginia—the Chesapeake Bay Bridge Tunnel—does not accept SmartTag.

Another primary goal with the VDOT Smart Tag system has been to provide ETC at no cost to the customer. Virginia's traffic does not approach the volume of some of the other states in the northeast corridor. Still, VDOT provides SmartTags at no cost and ETC services at no cost to the customers. Some toll authorities charge usage fees or require purchase of or deposits for the transponder while Virginia has been able to design and implement ETC that can be "free" to the customer.

With the state of Maryland now using E-Zpass, there are now more commuters in northern Virginia who could benefit from reciprocity with E-ZPass. VDOT has met with E-ZPass representatives several times to discuss some form of reciprocity. The goal is to achieve interoperability in a manner that will allow Virginia to maintain the separate SmartTag benefits. These benefits include no charge to customers, confidentiality of customer information, etc. Another challenge will be developing the appropriate interfaces between two systems that have different classification systems, different operations, etc.

In summary, the attractions for moving towards integration with another ETC system are:

- Increased convenience for travelers if they can use one system regardless of where they travel. This might be relevant to the Oregon study should Washington, California or Idaho ever pursue such an initiative.

- While it was originally suggested that costs could be reduced if Virginia participated, it was understood that participation in E-ZPass would increase costs, primarily due to the large number of other facilities that must be coordinated.

- The potential of not needing to establish a service center within the state and to be able to make use of an existing service center that was in operation.

The summary of reasons why joint operation with E-ZPass was not selected is:

- VDOT made a decision to seek as much local compliance and interoperability within the state as possible. It was very unlikely that all small toll road facilities could have participated had SmartTag gone with the E-ZPass option. One consideration in Oregon would be whether other payment systems would be desired to be linked with this system, such as airport parking payment, bridge toll payments, etc.

- VDOT was and is able to offer ETC at no cost to the travelers because of the low costs of operating the Smart Tag system. The extra compliance needed to participate fully with E-ZPass was expected to raise operations costs.

- Confidentiality of customer information was also a concern.

3.3 DATA PROCESSING OPTIONS

3.3.1 Processing Data From In-Vehicle Systems

Under the wide area data transmission option, it is assumed that the VMT would be calculated either on-board the vehicle or at the data and fee collection center. It is necessary to make some assumptions regarding frequency of data transmission. With on-board VMT calculation, for the sake of this comparison it is assumed that the VMT would be transmitted to the center once per month (more frequent transmission would raise the communications costs). With collection center VMT calculation, it is assumed that the raw location data stream would be transmitted to the center once per day. The on-board system would need to have sufficient capacity to store more than one day's worth of data in the case of communications failure. The on-board processing capabilities required would not be overwhelming given that the VMT estimate only requires basic mathematical operations. Under the data hub options, raw location data or VMT summaries would be aggregated at service stations, DMV facilities or field located RF tag readers for transmission to the service center. Details regarding costs for these options are provided below.

3.3.2 Data Transmission For System Options

Under the scenario of charging road users fees based on VMT, a critical component for ensuring that the correct fee is charged to users is effective transmission of data from vehicle devices to collection centers. One option is to use existing wide area communications systems. Technologies that fall into this category include cellular, satellite, and radio. The most extensive wireless infrastructure that exists is cellular communications. According to the Cellular Telecommunications and Internet Association (CTIA) in a survey where 2,261 of 2,587 systems operating in the U.S. responded, the number of cellular sites has increased 22.3% per year since 1985 through December 2001. This steady rise shows that telecommunications companies are continuing to increase cellular coverage across the nation. Radio transmission is also considered to be a form wide area communications; however, it is limited to short to medium range transmission. At this time, satellite communications is too cost prohibitive to be considered for data transmission between in-vehicle devices and collection centers. From a review of various commercial vendors, typical satellite airtime charges are over $1.00 per minute, not including the monthly access fees of $35 and up.

Another alternative involves the data hub approach. The communications that work well with this type of approach is typically short-range or low frequency requiring the vehicle to be within certain proximity of a service center. This type of communication is appropriate for service centers operating under the DMV or fuel station scenarios.

The other component, center-to-center communications, is not as challenging as most businesses and government agencies today require sharing and transfer of data between different locations. Further discussion of potential communications costs is included in the cost estimate section below.

3.3.3 Data Center

When considering options for the configuration of the service center itself, there are two important questions: will all data be stored in one physical location, and will each physical location contain one or more computers? Single machine “monolithic server” solutions have lost popularity over the past decade, largely for reasons of high cost and lack of incremental scalability. The shift away from monolithic approaches was made possible by technical advances in networking speed and memory and disk capacities. The alternative, a collection of interconnected less powerful computers used as a server, is commonly referred to as a cluster. The term “server” is commonly used for both monolithic and clustered approaches.

Regardless of the composition of each server (cluster, single server or mainframe), the key decisions to be made involve questions of data location and replication. In a truly distributed model, there may be no single server that contains all of the data. Each server stores a portion of the data, and there would be some way to locate data residing on other servers as needed. In a centralized model, there is one coordinating server that contains the full set of data. Each of a number of worker servers may gather data and report it to the coordinating server, or request data from the coordinating server and process it locally.

Scalability can frequently be achieved with a hierarchical approach, where some computation is done in a distributed manner, but one server eventually houses the full set of results. An example would be calculating mileage driven for each vehicle in a distributed manner, and then collecting all of the mileage totals in a central server for reporting, billing, audit functions and archiving. In a data hub scenario, with each vehicle reporting its data monthly, it would be reasonable to break down the total set of vehicles into a group of regions with one worker server for each data hub. Each hub can generate bills independently, as long as each vehicle (or customer) is assigned one and only one bill generation site. Summary statistics may be forwarded to a coordinating server at a central site for audit, archiving and report generation.

In a wide area scenario, with each vehicle reporting its location coordinates as often as once per day, and VMT calculated by the server at the data center, a logical division of the data is less obvious. Certainly the number of transactions that span servers is much higher than with the data hub scenario, since the distance calculations themselves might use data stored at different worker servers. Four key issues to consider in distributing server functionality are described in the following subsections.

3.3.3.1 Fault Tolerance

One of the potential advantages of any distributed approach is that the overall system can continue to function even if one component fails. This requires the software to include functionality to manage faults. When we replace a single part with a dozen parts (as in the cluster approach), the mean time to failure actually increases, since the mean time to failure in a collection of 10 parts is equal to one-tenth the mean time to failure of a particular part. An example of how a system addresses this is RAID—a protocol for using more than one commodity disk rather than one very large disk. Redundancy and error checking are built into RAID by necessity, since the laws of probability tell us the mean time to failure is much less than a single disk solution.

Tolerance to very large failures, such as a power failure or an earthquake, is frequently achieved by breaking up a central service center into three or more smaller centers that are geographically dispersed. If one center fails, some essential core of processing can continue, even though the remaining centers cannot handle 100% of the workload. Complete tolerance to such disasters, on the other hand, involves total redundancy, meaning each of the centers has the capacity to handle 100% of the workload, and each regularly stores a complete set of data.

3.3.3.2 Security

Currently available database systems and networking infrastructures provide mechanisms for securing data. For example, Oracle offers an option for their database that allows assignment of classification levels to different types of data. Data moving over a network needs additional security, and a variety of solutions including data encryption are in practical use. At a lower level, networks may make use of the Secure Sockets Layer (SSL) protocol to move data securely; wireless networks may use the analogous Wireless Transport Layer Security Specification (WTLS). Existing systems with sensitive data, such as stock trading from personal wireless devices and electronic toll collection, generally use a combination of available techniques to achieve security goals.

3.3.3.3 Incremental Scalability

Using a cluster of servers instead of one larger server allows the server to be scaled over time as the workload increases.

3.3.3.4 Data Coherence

Distributed systems introduce issues related to data coherence—put simply, if two servers each have a copy of the same data that differ slightly, which is correct? Currently available systems software provides solutions for this. For example, Oracle offers an optional cluster support package to manage functionality specific to clusters.

3.3.3.5 Customer Service and Support Needs

Details of customer service provision for a statewide VMT fee system are part of the design and ultimate implementation of a real system, but for purposes of this analysis and set of cost estimates, some basic assumptions must be made. Ultimately, important decisions about the number and scope of customer service facilities would need to be made. Looking to similar operations in the electronic toll collection industry, customer assistance options allow for walk-in or remote processing services.

Under one customer service model, a service center with walk-in support would allow the portion of the Oregon population not using electronic banking systems (credit or debit cards, for example) to directly pay for VMT fees with cash. Those users more comfortable with face-to-face service will likely use these service centers. This support option is comparable to DMV facilities in current operation around the state. While DMV facilities do not currently accept credit or debit charges, these walk-in service centers for the VMT fee system could provide on-site acceptance of cash, check, or charge payments to increase user convenience. Detailed breakdowns of preferred customer payment mechanisms could be determined via public survey tools or could be limited by policy.

Staffing requirements for walk-in service would need to include personnel to process payments, answer questions, and perform other customer interactions. Walk-in service centers could also provide troubleshooting or replacement of faulty VMT reporting devices. Walk-in service hours should operate eight hours a day for at least five days a week. Half-day service hours should be provided during the weekend similar to DMV hours.

Another option would be to set up remote customer service centers without walk-in support. This center would primarily serve to process electronic forms of payment and billing cycle requirements. At such locations, Internet and Interactive Voice Response (IVR) or similar telephone applications could be set up to provide telephone service support. These applications would allow for customer self-help with access to account information and similar functions. Internet support would provide for even more flexibility and options in servicing customers. The Internet could be used by customers to check accounts, submit payments, and to access information regarding the collection of fees. Internet support could help reduce the cost of operating and maintaining a telephone help system. However, this application would only reach users with Internet access.

Setting up a combination of the two types of service centers would provide the most flexibility and options for reaching out to the greatest number of road users possible.

3.3.3.6 Billing Options

Another function of the service center is to generate billing statements. A number of billing options exist. A typical scenario is to set up a monthly billing cycle. In this scenario, the user is charged on a monthly basis based on the vehicle miles traveled for the previous month. A billing statement would be sent to the user. The user would have the option of paying by cash, credit card, or check. Cash would only be accepted at collection centers with walk-in service. The cost for maintaining a monthly billing system include printing and postage fees as well as staff to handle the remittance of payments. Some electronic toll collection agencies offer users incentives to accept less frequent (i.e. quarterly) billing or paperless billing via e-mail. These measures could be implemented in order to reduce administrative costs.

A slightly different alternative would allow users to prepay fees based on expected VMT for a specified time period. The user can estimate the average vehicle miles traveled on a yearly or monthly basis. Users selecting this billing option would receive an incentive for advanced payment (e.g., 5% discount of actual cost for prepaying one year, 2.5% for prepaying on a monthly basis). This would be similar to credits provided to homeowners for advanced payment of property taxes. The user would then receive a refund or be billed at year-end for the difference. This alternative could be used in conjunction with other scenarios.

An option that would ensure more frequent payments of the road user fee would be a per transaction payment scenario. This option would be most applicable for technologies such as automatic vehicle identification (AVI) tags or debit/credit/smart card mechanism at service stations. In the AVI tag scenario, a user's account is decremented a certain amount based on the VMT each time the user pulls up to an active tag reader station. As the funds in a user's account diminish, the user can replenish the account by submitting additional funds. In the service station scenario, the user is charged at the pump for road user fees based on the VMT calculated on-site. In both cases, a fee statement could be mailed out every quarter or at year-end. This scenario would ensure frequent payment of fees and allow for user convenience. However, the cooperation of service stations would be required. The submittal of fees via service stations would require an additional mechanism to funnel funds from third party collectors to the state.

Some considerations for billing options include the cost of frequent processing of accounts. Billing generation can be costly due to printing fees and postage, and handling considerations. The cost of monthly billing generation to the entire driving population in Oregon could become significant. However, in some real world instances, such as with the SmartTag electronic toll collection system in Virginia, to offset costs users are sent a free summary statement every three months. More frequent and detailed statements are available for extra cost, starting at $2.00 per month.

The other consideration for using electronic payment methods is the transaction fees charged by credit card companies. Credit card payments, while convenient, require average fees of 2.5 to 3.75 percent (*Castle Rock 2001*) of the transaction charges.

3.4 EXISTING SYSTEM COMPARISON

Service centers from a number of industries provide a good source of comparison. These sectors include tolling facilities, telematics, public safety answering points (PSAPs), utilities and state lottery systems.

3.4.1 Toll Collection Centers

3.4.1.1 Virginia

The SmartTag electronic toll collection facilities in Virginia operate on 7 toll roads and over 150 toll lane collection areas. SmartTag processes approximately 9 million transactions per month. The system operates using transponders placed on the inside windshield of a vehicle. As the vehicle passes through a reader installed on the roadway, the amount of the toll is deducted from a user's account. Communications between the transponder and readers is via short range RF. The transponder has a range of approximately 100 m. Data sent from the transponder is collected at the roadside and transmitted back to the service center over standard telephone lines.

The SmartTag service centers are set up on a distributed network. There are service centers in Reston, Richmond, and at the Coleman Bridge. The current back office system and call centers are in Reston. The SmartTag center infrastructure uses leased lines and frame relay connections of at least 56 kbps for connections between service centers and toll facilities. The system is capable of transmitting toll lane transactions and transponder update information. Toll lane transactions include: date, time, location, vehicle class, transaction type and tag number; disbursement summaries and details of daily revenue; non-revenue transaction activity; account updates; and toll gate violation data.

The SmartTag collection centers operate on a prepayment system whereby each user is set up with a customer account. This account is decremented each time the user drives through a SmartTag facility. If a driver does not have a proper account, the tollgate will not open and the driver's license plate will be recorded by video surveillance. The presence of a tollgate makes compliance relatively easy to enforce. Users can open accounts by walk-in, telephone, Internet, mail, or fax. The incentive for customers to choose automatic replenishment of account is to waive the deposit for the transponder ($15.00). Customer service operating hours are 9:00 am to 5:00 p.m., Monday to Friday, for some locations. Others are 10:00 am to 6:00 p.m., Monday to Friday. One service center is open from 9:00 am to 1:00 p.m. on Saturday. Patrons can dial into an interactive voice response, 24-hour telephone number to access account status, queries, and general information. Free quarterly summary statements are automatically mailed to customers. Detailed monthly statements are available; however, for a fee of $2.00 per 3 transponders on the account.

3.4.1.2 SR 91 Express Lanes

The SR 91 Express Lanes are electronic toll facilities operated by the California Private Transportation Company (CPTC). The express lanes are situated between the public access lanes of SR 91 in Orange County, California. The lanes serve approximately 130,000 active customers. Like the Virginia facilities, this system uses transponder technology to charge vehicles for their use of the roadway. The FasTrak company provides the transponders, but the California Private Transportation Company maintains customer accounts and provides all customer service.

Data are transmitted from the receivers to the center via T1 and fiber optic cables to a centralized data center. Transmissions include the unique identifier of the transponder, the facility code, the location of the toll plaza through which the vehicle passed, and the date, time, and lane direction of the particular transaction. The CPTC considers information about monthly transaction volume proprietary. The system employs fail-over back up, and houses concurrent data at a location separate and distinct from the primary data center.

The SR 91 Express Lanes maintain one customer service center and one processing center. The customer service center employs 22 personnel and provides customer service both at the counter and over the telephone. The center's call volume is 8,000 calls per week and the cost per call is approximately three dollars. The processing center employs 11 personnel who mail bills, quarterly statements, information, and transponders to customers.

Customers of the 91 Express Lanes pay for the service much in the same way as do those in the Virginia system. Drivers establish prepaid accounts with the company, and the cost of each trip through the facility is deducted from this account. In some cases, the customer's credit card is automatically charged to replenish their account when the balance is low. The SR 91 Express Lanes provide self-service payment options by Internet and telephone. Most customers choose these options and pay by credit card, but walk-in service is also available at the customer service center, from 9 am to 6 p.m., Monday through Friday. Customers receive quarterly account statements from the company.

3.4.2 Telematics Centers

The automobile industry has developed a concept called telematics, which combines embedded cellular communications, location capability using global positioning systems (GPS) and in-vehicle computing to enable drivers to take advantage of services such as airbag deployment notification systems; one button emergency call; roadside assistance call; stolen vehicle tracking; remote door unlock; door-to-door navigation systems; personalized concierge systems; access to consumer information such as news, weather, sports, stocks and traffic conditions; and remote vehicle diagnostics. For example, if a vehicle is involved in a crash and the airbag deploys, the telematics system will automatically call the service center via the embedded cellular phone, and provide the vehicle's identification and location. An operator will attempt to make voice contact with the occupants. At the same time, the operator will dispatch the appropriate emergency services to the vehicle's exact location. General Motors has developed its own service entity called OnStar, while most other auto makers use a service provider called ATX Technologies.

3.4.2.1 ATX Technologies

In 1999 San Antonio-based ATX Technologies acquired Dallas-based Protection One Mobile Services Group. Both companies had played a role in the beginning of what is now called the telematics industry, combining location and communications to provide security and convenience services to drivers across the U.S. In 1996, with Ford and Motorola, ATX developed the first in-vehicle emergency response (MAYDAY) system that integrated location-based, GPS satellite technology with hands-free cellular telecommunications and 24-hour call center response. This first system was known as the Lincoln RESCU system. ATX now provides telematics services primarily to auto manufacturers and some after market systems. Current customers include Mercedes-Benz, Ford, Jaguar, Lincoln-Mercury, Infiniti, BMW and Greyhound.

ATX created the Public Safety Answering Point (PSAP) database (for the Ford RESCU) which is now used nationwide. This database was necessary so that the call center operator could contact the appropriate emergency 911 response center for the actual location of the vehicle involved in the crash. Prior to this, there was no such national database. ATX maintains National Response Centers in Dallas and San Antonio. The Dallas facility (opened in November 1999) has a capacity to monitor one million vehicles. ATX currently handles more than 50,000 vehicles and expects to reach its current center capacity by 2005. Various auto manufacturers offer telematics services provided by ATX under several particular brand names. Monthly service costs fall into a range similar to OnStar (see below).

3.4.2.2 OnStar

The OnStar Center operates 24 hours, 7 days a week providing emergency assistance, concierge, driving assistance and other services. OnStar service is offered to subscribers of the in-vehicle devices available in 34 out of 54 different 2002 GM vehicle models. The in-vehicle device uses cellular and global positioning system technology to communicate voice and data to the call center. The service costs range from $16.95 to $69.95 per month. Each level of service provides basic support such as emergency notification, stolen vehicle tracking, remote diagnostics and other concierge services. While all devices are GPS equipped, OnStar ensures customer privacy by only locating the vehicle in the event the OnStar button in the vehicle is pressed, if the air bag is deployed, or vehicle is reported stolen. OnStar service representatives require cellular connectivity and vehicle power to perform diagnostics checks and receive location data.

The OnStar service center handles routing requests, remote door unlock requests, roadside assistance requests, air-bag deployments and location of stolen vehicle requests. Over 1,000 call center operators provide support to over 2 million subscribers of the service (*Warner 2002*). OnStar customer service center locations in North Carolina, Michigan, and Ontario, Canada provide nationwide US and Canada support to OnStar subscribers.

3.4.3 Other Systems

Several other types of systems are in place in Oregon that are responsible for data transmission, processing and billing. Brief consideration of these systems is included below.

3.4.3.1 Oregon State Lottery

The Oregon State Lottery contracts with 3,300 retailers across the state. The retailers pay for phone line installation and monthly charges, and the state provides equipment service and sales commissions. Commercial vendors provide the games. The lottery is self-financed, and is required by law to spend no more than 16 percent of their total annual sales on administrative costs. Major expense categories include retailer sales, game vendor expenses, and lottery administration.

The lottery maintains a 24-hour central computer system. Three main computers manage three separate areas: online games, the video lottery, and internal operations. Transmission of data between retailers and the lottery data center is conducted via standard telephone lines.

3.4.3.2 Public Safety Answering Points (911)

Oregon's 9-1-1 program links 56 Public Safety Answering Points (PSAPs) across the state and is administered by Oregon Emergency Management. Recent technology upgrades to the system now provide border-to-border Enhanced 9-1-1 services. The system utilizes a statewide frame network to connect the PSAPs, which provides high-speed connections that allow for fast delivery of Automatic Number Identification (ANI) data. The network is also cost effective, as it can accommodate other types of data on the same circuit. In addition to these advancements, Oregon provides wireless services including cell site location and call back number of the wireless caller for multiple carriers.

3.5 DATA AND FEE COLLECTION CENTER COST ESTIMATES

Capital (initial) and annual operations costs were estimated for the fee collection center scenarios noted earlier in this report. These data transmission options are:

- Wide area location – In this scenario, it is assumed that raw location data is transmitted from the vehicle to the data and fee collection center once a day using cellular communications.

The data stream consists of raw location data, which will be converted to VMT at the data and fee collection center.

- Wide area VMT – The assumption is that the VMT will be calculated in the vehicle and transmitted via cellular to the data and fee collection center once a month.

- Hub – In data communications, a hub is a place of convergence where data arrives from one or more directions and is forwarded out in one or more other directions. The hub scenario assumes that vehicles will provide a raw location or VMT data upload to the service station or DMV hub for aggregation and transfer to the fee collection center on a frequent basis. The frequency of data transmission does not greatly impact costs as the landline communications fees are charged on a monthly rather than per transaction basis.

Cost estimates provided below would be generally applicable for fixed VMT fees (applied on a statewide basis). These would also be valid and for situations where variable pricing were applied on particular corridors or within particular cordon areas. The estimates were developed assuming that approximately 3 million vehicles traveling on Oregon's roads will be paying fees. The system envisioned here would be approximately revenue neutral, recovering an estimated $390 million a year in road user fees. Further, real-world operating costs from the SmartTag service center in Virginia for year 2002 were used as reference in generating operations estimates for the data and fee collection center. Other assumptions will be detailed in the following section.

During the implementation phase, important customer service decisions would need to be made. For the purposes of these cost estimates, some allocation is made for operating costs for establishing some quantity of satellite customer service centers across the state. As a basis for providing a cost estimating framework, and because 95% of Oregon's driving population lives within 30 miles of a DMV facility, it has been assumed that satellite customer service centers would be located in or near existing DMV offices. This does not imply that this is actually physically feasible, since existing DMV facilities may be operating at capacity. The costs for the satellite customer service centers are not included in Table 3.1, but are presented in a subsequent table.

Table 3.1: Data and Fee Collection Cost Estimates

	Wide Area Location Data $ Million*	Wide Area VMT Data $ Million	Service Station or DMV Hub $ Million
CAPITAL COSTS			
Server Hardware	1.00-2.00	0.10	0.10
Communications Hardware	1.00-1.92	0.08	N/A
Software	1.00-1.60	0.60	0.60
Subtotal Capital Costs	3.00-5.52	0.78	0.70
Contingency (20%)	0.60-1.10	0.16	0.14
TOTAL CAPITAL COSTS	**3.6-6.6**	**0.94**	**0.84**
ANNUAL COSTS			
Telephone & Data Communications	55.00	5.00	2.00
Data & Fee Collection Center			
Rent	0.20	0.20	0.20
Electricity	0.25	0.25	0.25
Equipment/Furniture	0.06	0.06	0.06
Operations			
Customer Relations	1.00	1.00	1.00
Credit Card Fees	14.00	14.00	14.00
Software/Hardware Maintenance	0.60-1.10	0.16	0.14
Office Supplies	0.25	0.25	0.25
Statement Generation/Postage	18.00	18.00	18.00
Repairs/Maintenance	0.30	0.30	0.30
Labor	1.84	1.84	1.84
Satellite Customer Service Centers	1.40-4.20	1.40-4.20	1.40-4.20
Subtotal Annual Costs	92.9-96.2	42.5-45.3	39.4-42.2
Contingency (20%)	18.6-19.2	8.5-9.1	7.9-8.4
TOTAL ANNUAL COSTS	**111.5-115.4**	**51.0-54.4**	**47.5-50.6**

* Cost estimate range due to potential limitation of data transmission to off-peak hours.

The following describes in detail the assumptions behind the cost estimates and the methodology used to derive them.

3.5.1 Capital Costs

These refer to one-time costs and are mostly associated with computer equipment. This section details pricing estimates for the purpose of comparing the relative costs for the different specific scenarios, to identify trends and key pricing points. List or typical market prices are used here, rather than specific bids or estimates from vendors. It is fair to regard them as high estimates, and to assume that for an actual implementation a miscellaneous category would be added for smaller items that do not vary across the scenarios. Here we have listed out main costs with focus on costs that will vary between scenarios.

Typical server transactions include:

- New vehicle into Oregon
- Vehicle retired or moved out of state
- Vehicle totaled
- Vehicle changes owners within Oregon
- Onboard data uploaded to server
- Vehicle stolen
- Stolen vehicle recovered
- Bill generated
- Bill paid
- Summary reports

We focus on data upload to server for our measurements, since it is the most variable with respect to scenario, and also key to capacity estimation used to choose the category of server required.

The most popular options for database server software are products from Oracle and IBM. We use Oracle in our pricing examples; however, this should not be interpreted as a purchase recommendation of one product or vendor over another. Oracle is used by a number of well-known customers in Oregon:

- OHSU
- Oregon Department of Transportation
- Pacific Continental Bank
- Tektronix
- Multnomah County Educational Service District
- Public Safety Coordinating Council of Multnomah County
- Great Western Chemical

Several important features are currently available with the database, addressing concerns raised elsewhere in the report, including the Oracle Database Enterprise Edition with Advanced Security, Real Application Clusters (addresses single system image concerns), Label Security (allows security levels to be specified for different data items) and Advanced Security (provides all current security standards e.g., SSL). Finally in terms of the operating system, Unix-based servers are common, and Linux has been growing in popularity as an operating system for servers. Microsoft Windows is the other main option. The popular database vendors provide versions of their product for either.

3.5.1.1 Data Transmission Option 1: Wide Area With Location Data

In this option, each vehicle transmits a stream of data (time, x, y, ID) at some frequency to be determined. The VMT is not computed onboard the vehicle; rather, it is computed at the server. Assumed parameters include 3 million vehicles registered in Oregon, one daily upload per vehicle, and 1-minute connection time per upload as a rough estimate. The number of available phone lines to a given site may be limited, and the particular limit is specific to each location. This begins to be an issue at approximately one thousand simultaneous connections. Our cost estimate assumes the necessary phone lines are available. A separate data archival process will be necessary.

Hardware costs include costs for the dialup service and servers. The dialup device converts between phone circuits to IP (network protocol). One dialup device in common use today handles 8 T1 lines (approximately 192 connections) and costs approximately $80,000. To handle 3 million daily uploads of 1-minute duration, the system must handle 3 million minutes or 50,000 hours of transactions in a 24-hour time period. This requires approximately 2,100 simultaneous transactions or connections. This requires 12 dialup devices, so the cost would be approximately $1 million.

A rough sketch of necessary server capacity can be determined to an order of magnitude with some preliminary estimates. Using the estimate of 2,100 simultaneous uploads, and a data size of 3,200 bytes per upload, leads to an estimated maximum data upload rate of 9.7 Gigabytes per day. The total storage requirement for one year of summary data is approximately 3.5 Terabytes. An example of a server with this capacity is the SUN Fire 6800 Server, costing approximately $900,000 with 8 processors plus storage. Additional miscellaneous hardware would include several small Linux boxes, monitors, backup media, cables etc., at approximately $200,000.

Software costs would include database software licenses ($80,000 per processor from Oracle pricing), or approximately $640,000. Additional software customization and installation would be roughly $250,000, for a total software cost of about $1 million.

The strongest backup option, total redundancy, involves roughly doubling these costs. Intermediate backup options (for example offsite storage of data copies) would add to, but not fully double, these costs.

The previous discussion assumes that data transmission is spread over a 24-hour day. It is possible that transmission would be limited to off-peak hours, due to the limits of an agreement negotiated with a cellular service provider. The following paragraph examines how the capital costs would be affected by such a limit.

The total of 50,000 hours of transmission time would be spread over 12 hours (instead of 24 as above), thus requiring 4,200 simultaneous connections. The capacity needs would approximately double as a result of this change, even though total data storage would be the same. With a total need for 24 dialup devices at a cost of $80,000, the dialup cost would be $1,920,000. Two servers would be required at $900,000 each for a total server cost of $1,800,000. With an allocation of $200,000 for miscellaneous equipment, the total hardware cost would be $3,920,000. The database licenses would total $1,280,000; customization and installation would be approximately $320,000; thus the total software costs would be $1,600,000. With 15% for maintenance and an additional 20% contingency, this system would then have a total capital cost of $7,620,000.

3.5.1.2 Data Transmission Option 2: Wide Area With VMT Data

In this option, the mileage total is calculated onboard. The total is forwarded at some regular interval (monthly for example) directly from each vehicle to the server. It is assumed that there are 3 million vehicles registered in Oregon with one upload monthly per vehicle.

Hardware costs include equipment for the dialup service and for servers. There are an estimated 3 million uploads per month (compared to 3 million per day in Option 1), and the size of each upload is 32 bytes, requiring 25 simultaneous connections. This requires one dialup device costing approximately $80,000. Server capacity requirements are also lower than in Scenario 1. Approximately 3.5 Megabytes of new data will be uploaded daily, for an annual estimate of 10 Gigabytes. One example of a server in the appropriate order of magnitude is a SUN Fire V480 server with 4 processors, costing $50,000. There is an accessory cost for several small Linux boxes, monitors, offsite backup media, etc. for an additional $100,000.

Software costs include database software licenses ($80,000 per processor from Oracle pricing) at about $320,000 and software customization and installation for an additional $250,000. The total approximate software estimate is $600,000.

3.5.1.3 Data Transmission Option 3: Data Hub

In this option, distance traveled is calculated at one of a number of data hubs. Each data hub transmits total miles traveled for each of a number of vehicles at some frequency, for example, monthly. Two possible data hub options are: DMV hubs (68 DMV locations) and service stations (about 1,800 service stations in Oregon). It is assumed that one record is uploaded per vehicle per month. It is also assumed that data streams into the service center via standard landline phone systems or other existing statewide computer network (using standard internet protocols).

No dialup devices are needed for this scenario. The server must be capable of processing approximately 66 megabytes of data per month, or 10 gigabytes annually. The estimated cost with an example of a SUN Fire V480 server with 4 processors is $50,000 and a few small Linux boxes, monitors, offsite backup media, cables etc., for an additional $100,000.

Software costs include database software licenses at $80,000 per processor (from Oracle pricing) for a total of $320,000 and software customization and installation at an additional $250,000. This leads to an approximate total of $600,000 for software.

3.5.2 Annual Costs

Annual costs refer to items that represent routine costs. The cost of communications between the on-board device and the data center (in the case of cellular) or between the reader station and the hub (in the case of the service station or DMV reader locations) are included, as are the costs associated with the data center itself.

3.5.2.1 Telephone and Data Communications

Estimates for the cost of communications between the data and fee collection center and the data transmission device vary greatly among the three items. This cost is largely dependent on the frequency of transmission. The estimates assume that each data transmission will take one minute or less, and that the charge per one minute of airtime is $0.05. The charge-per-minute assumption is based on rates negotiated by other government agencies for data transmission.

The first estimate of $55 million is based on the use of wide area communications and assumes that the on-board device is transmitting location data to the data center. VMT would then be calculated at the center. In this scenario, the vehicle would transmit location data once a day. The total was derived from the assumption that 3 million vehicles would conduct one 1-minute cellular transmission per day, each day of the year. This cost could be reduced if the agreement with the cellular service provider(s) called for communications only during off-peak periods.

The second estimate of $5 million uses the same equation, but bases the cost on one transmission per month rather than one per day. The data transmissions occur less frequently because in this scenario the on-board device calculates the VMT, so there is less data that must be transferred to the data center. The third estimate makes the same assumption about transmission frequency. Transmissions would occur via landline in this scenario, so the $2 million estimate, which includes an allocation for hub-to-center communications, would be a ceiling.

3.5.2.2 Data and Fee Collection Center

The cost estimates for the data and fee collection center are based on the annual operating budget of SmartTag facilities in Virginia. The number of vehicles in Oregon (3 million) is roughly three times greater than the service population of SmartTag, so the line items were multiplied by three unless otherwise noted.

- *Rent*: These estimates are based on a monthly rate of $25 per square foot per year, the commercial rental rate for "Class A" property in downtown Portland. The estimate of $0.2 million includes the cost of security and property insurance and space for standard back-up systems. The table assumes that an 8,000 square foot facility would be required.

- *Electricity*: The electricity estimate was calculated by generating a utility cost per transaction for the SmartTag facilities, and then applying that ratio to the number of expected transactions in the Oregon system. Server power requirements determined under a more detailed design process could necessitate special air conditioning and power requirements. Also, uncertainties relating to future electricity costs in the western U.S. could impact this cost estimate dramatically.

- *Equipment and Furniture*: This estimate is the result of multiplying the SmartTag budget by three.

3.5.2.3 Data and Fee Collection Center Operations

The cost estimates provided here do not include tax evasion enforcement costs. Basic non-payment and collections issues relating to customer relationships between drivers and the center, however, are included in the cost allocated for billing and statement processing.

- *Customer Relations*: This charge includes the cost of producing and distributing marketing materials such as brochures, posters, etc. Other printing costs are also included. The cost estimate was calculated by multiplying the SmartTag advertising budget by three.

- *Credit Card Fees*: Credit card companies charge SmartTag fees of 2.5 to 3.75 percent of each transaction. The estimate assumes the program is revenue neutral, so the credit card fees would be a percentage of $390 million in annual revenue. Given the range listed above, the possible cost per year would be $9.25 to $14.625 million. A maximum value of approximately $14 million is used in the cost estimate.

- *Administrative Software Costs*: It is assumed that hardware and software maintenance costs will add up to approximately 20% of the total hardware and software cost. Annual variable costs, which might include upgrades, maintenance, etc., are not expected to exceed twenty percent of the total cost.

- *Office Supplies*: The cost estimate was calculated by multiplying the SmartTag office supplies budget by three.

- *Statement Generation*: SmartTag distributes quarterly statements to approximately 300,000 customers. The statement estimate was calculated by generating a cost per statement for the SmartTag facilities. The ratio was then applied to the number of statements expected to be generated in the Oregon system for three million vehicles if they were generated on a monthly basis. The calculation is based on 36 million statements a year at a cost of $0.50 per statement including postage. Customers could be offered incentives to conduct transactions by telephone or via the Internet as a means of saving statement preparation costs.

- *Repairs/Maintenance*: The cost estimate was calculated by multiplying the SmartTag repairs and maintenance budget by three.

- *Labor*: Without an actual system design, it is difficult to determine the staff size necessary at a central data and fee-processing center. The cost estimates shown in Table 3.2 below were based on the number of personnel listed in the table below.

Table 3.2: Data and Fee Collection Center Labor Cost Estimates

Position	Salary (per employee)	Benefits (per employee)	Total (all employees)
Managers (2)	$60,000	$60,000	$240,000
IT (8)	$37,500	$37,500	$600,000
Clerical/Customer Service (20)	$25,000	$25,000	$1,000,000
Total (30 employees)			$1,840,000

3.5.3 Customer Service Center

As a means of defining some framework for considering the cost impact of providing distributed customer service capabilities at a reasonable number of statewide locations (e.g., DMV facilities or other public properties), a cost allocation table (Table 3.3) was developed for operating a simple customer service station at an existing office facility. This makes the bold assumption that there is such space available for this purpose. In reality, a new employee may not need to be hired, but existing employees would need to be trained in the new VMT pricing system.

Table 3.3: Customer Service Center Cost Estimates

Cost Element	Cost
Workspace	$36,000
Equipment	$5,000
Operations	
Customer Relations	$10,000
Software Variable Costs	$5,000
Office Supplies	$10,000
Labor	$50,000
TOTAL	$116,000
20% Contingency	$23,200
TOTAL COST ESTIMATE	$140,000

This rough estimate is based on the cost of adding a customer service counter at an existing office facility and was calculated using the methods described in section 3.5.2. It is assumed the VMT customer service station would include the following elements:

- One clerical/customer service position
- 10 ft x 10 ft cubicle space
- Desktop computer and other equipment appropriate for one employee
- Office supplies appropriate for one employee
- Appropriate software upgrades

At present there are 68 DMV facilities in the state. If a range of 10-30 such facilities were allocated, this would add approximately $1.4 million to $4.2 million to the annual cost estimate.

3.6 DATA TRANSMISSION OPTIONS SUMMARY

In summary, there are two primary options for setting up fee collection centers. These alternatives are wide area and data hub. In the wide area option, either calculated VMT or raw location data is transmitted from the vehicle to collection centers using cellular communications. Data is transmitted from the vehicle to the center at frequent intervals (e.g., daily or monthly). In the data hub option, calculated VMT or raw location data is transmitted from the vehicle to an intermediary reader located at DMVs or fuel stations. This requires the road user to pull up to a roadside facility to perform the data upload.

In either data transmission option, data from the vehicle may then be processed at centralized or distributed centers. The centralized configuration assumes that one data center is responsible for the collection of all VMT or raw location data. The distributed center option allows for data transmitted from vehicles to be sent to a number of centers for processing. Transmission of data may be accomplished by way of cellular (directly from vehicle to center) or RF (from vehicle to hub). Landline communications is required to transfer data from RF hubs to centers. Landline communications may also be used for communications between service centers.

Fee payments calculated from the processed VMT data may occur through billing cycles or direct payment at hubs. User fees processed via billing cycles is the only system for the wide area option. Statement generation may be based on the VMT calculated for a certain time interval and road users are sent a periodic statement. Billing cycles may also be appropriate for data hubs co-located at DMVs. These statements would be generated in a manner similar to the wide area option. An alternative payment approach for data hubs may occur on a per transaction basis whereby road users pay the appropriate fee at the fuel station. In the technology options where complete direct payment occurs at the hubs, then the data center would not be necessary.

For both wide area and data hub transmission options, the same customer service needs exist. Walk-in customer service may be required for those accustomed to paying for service with cash, especially if VMT fees are processed on a monthly basis. The walk-in service center could also provide other services such as reconciling accounts, answering questions, and performing functions similar to servicing DMV patrons. Another type of customer service center is one that does not provide customer service support and manages the processing of data and bill generation. Support is provided electronically, for example, through telephone or the Internet.

Table 3.4 summarizes considerations for the various component options for establishing fee collection centers:

Table 3.4: Configuration Options

System Options	Considerations
Wide Area	• Requires reliable and secure cellular network. • Greater user convenience as data transmission is seamless.
Data Hub	• May be inconvenient for users to visit hubs located at DMVs more than once a year.
Center Options	
Centralized	• Need to establish back up system to address disaster recovery. • Necessary back up system may be costly, but required. • Back up system inactivity may result in unstable operating environment.
Distributed	• Greater capital and operating costs. • Multiple processing points allow for back up system to exist within network.
Data Transmission	
Cellular	• Airtime charges for frequent data transmission may prove cost prohibitive.
RF/Landline	• Requires road user to be within a certain data frequency range data hub to upload data. • Cheaper alternative as landline charges are independent of frequency of data transmissions.
Customer Service and Support Needs	
Walk-In Service	• Need to consider multiple methods of payment to ensure user convenience. • Provides support to greater number of road users.
No Walk-In Service	• Lack of options for road users wanting in-person assistance. • Requires less staff to operate service centers.
Billing Options	
Statement generation frequency	• Frequency of billing affects operations costs associated with statement generation, postage, handling, and materials cost. • Infrequent billing cycles will not allow the state to recoup fees at regular intervals to support programs.
Payment options	• Cash payment requires walk-in service support and extra staffing at service centers. • Credit card transaction costs range from 2.5 to 3.75 percent of charges.

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