



# HCAS Supplementary Documents

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# Appendix A: Glossary

## GLOSSARY OF HIGHWAY COST ALLOCATION TERMS

### LIST OF ACRONYMS

<b>AAA</b>	American Automobile Association
<b>AMT</b>	Axle Miles of Travel
<b>ATR</b>	Automatic Traffic Recorder
<b>DAS</b>	Department of Administrative Services
<b>DL</b>	Dead Load
<b>DMV</b>	Division of Motor Vehicles
<b>ESAL</b>	Equivalent Single Axle Load
<b>FHWA</b>	Federal Highway Administration
<b>HCAS</b>	Highway Cost Allocation Study
<b>HPMS</b>	Highway Performance Monitoring System
<b>LL</b>	Live Load
<b>MCTD</b>	Motor Carrier Transportation Division
<b>NAPCOM</b>	National Pavement Cost Model
<b>NAPHCAS</b>	National Pavement Model for Highway Cost Allocation
<b>ODOT</b>	Oregon Department of Transportation
<b>OHCAS</b>	Oregon Highway Cost Allocation Study
<b>OTIA</b>	Oregon Transportation Investment Act
<b>PCE</b>	Passenger Car Equivalent
<b>SRT</b>	Study Review Team
<b>VMT</b>	Vehicle Miles of Travel
<b>WIM</b>	Weigh-In-Motion

### DEFINITIONS

**Alternative Fee:** A fee charged to some vehicles in place of the usual fee (e.g., a lower registration fee for publicly owned vehicles).

**Arterial:** A road or highway used primarily for through traffic.

**Attributable Costs:** Costs that are a function of vehicle size, weight, or other operating characteristics and can therefore be attributed to vehicle classes based on those characteristics.

**Axle Miles of Travel (AMT):** Vehicle miles of travel multiplied by number of axles. Because trucks, on average, have roughly twice as many axles as cars (i.e., four versus two), their share of the total axle miles of travel on any given highway system will be about double their share of the vehicle miles of travel on that system.

**Axle Weight or Axle Load:** The gross load carried by an axle. In Oregon, 20,000 pounds is the legal maximum for a single axle and 34,000 pounds is the legal maximum for a tandem (double) axle.

**Benefits:** Things that make people better off, or the value of such things.

**Collector:** A road that connects local roads with arterial roads.

**Common Costs:** Expenditures that are independent of vehicle size, weight, or other operating characteristics and so cannot be attributed to any specific class of vehicles.

These expenditures must therefore be treated as a common responsibility of all vehicle classes and are most typically assigned to all classes on

the basis of a relative measure of use, such as vehicle miles of travel.

**Cost Allocation:** The analytical process of determining the cost responsibility of highway system users.

**Cost-Occasioned Approach:** An approach that determines responsibility for highway expenditures/costs based on the costs occasioned or caused by each vehicle class. Such an approach is not based solely on relative use, nor does it attempt to quantify the benefits received by different classes of road users.

**Cost Responsibility:** The principle that those who use the public roads should pay for them and, more specifically, that payments from road users should be in proportion to the road costs for which they are responsible. The proportionate share of highway costs legitimately assignable to a given vehicle type user group.

**Cost-Based Approach:** An approach in which the dollars allocated to the vehicle classes are measures of the costs imposed during the study period, rather than expenditures made during the study period. The difference between the cost-based and expenditure-based approaches is most evident when considering large investments in long-lived structures and when deferred maintenance moves the expenditures associated with one period's use into another period.

**Cross-Subsidization:** A condition where some vehicles are overpaying and others are underpaying relative to their respective responsibilities.

**Dead Load:** The load on a bridge when it is empty.

**Debt Financing:** Funding current activities by issuing debt to be repaid in the future.

**Debt Service:** Funds used for the repayment of previously incurred debt (both principal and interest).

**Deck:** The roadway or surface of a bridge.

**Declared Weight:** In Oregon, vehicles choose a declared weight and pay the weight-mile tax based on that weight. They may not exceed that weight while operating without obtaining a special trip permit. For tractor-trailer combinations, a single tractor may have multiple declared weights, one for each configuration it expects to be a part of.

**Depreciation:** The amount of decrease in value of a physical asset due to aging in a time period.

**Efficiency:** The degree to which potential benefits are realized for a given expenditure.

**Efficient Pricing:** Setting prices for the use of highway facilities so that each vehicle pays the costs it imposes at the time and place it is traveling. Efficient pricing promotes the most efficient use of existing facilities and generates the right amount of revenue to build the most efficient system and perform the optimal amount of maintenance.

**Equity:** Generally interpreted as the state of being just, impartial, or fair. Horizontal equity refers to the fair treatment of individuals with similar circumstances. Vertical equity refers to the fair treatment of individuals in different circumstances.

**Equity Ratio:** The ratio of the share of revenues paid by a highway user group to the share of costs imposed by that group.

**Equivalent Single Axle Load (ESAL):** The pavement stress imposed by a single axle with an 18,000-pound axle load. ESAL-miles are equivalent single-axle loads times miles traveled. Research has concluded that the relationship between axle weight and ESALs is an approximate third- or fourth-power exponential relationship; ESALs therefore rise rapidly with increases in axle weight.

**Excise Tax:** A tax levied on the production or sale of a specific item such as gasoline, diesel fuel, or vehicles.

**Expenditure:** The amount of money spent in a time period.

**External Cost:** A cost imposed on individuals who do not use the facility.

**Federal Highway Funds:** Funds collected from federal highway user fees and distributed to states by the Federal Highway Administration for spending on transportation projects by state and local governments.

**Functional Classification:** The classification of roads according to their general use, character, or relative importance. Definitions are provided by the Federal Highway Administration for Rural Interstate, Rural Other Principal Arterial, Rural Minor Arterial, Rural Major Collector, Rural Minor Collector, Rural Local, Urban Interstate, Urban Other Expressway, Urban Other Principal Arterial, Urban Minor Arterial, Urban Collector, and Urban Local.

**Fungibility:** The relative ability to use funds from different sources for the same purposes. Funds from some sources carry restrictions on how they may be spent; to the extent that those funds free up unrestricted funds that would otherwise be spent that way, they may be considered fungible with the unrestricted funds.

**Gross Vehicle Weight:** The maximum loaded weight for a vehicle.

**Heavy Vehicles:** All vehicles weighing more than the upper limit in the definition of a light (basic) vehicle (see light vehicle). Includes trucks, buses, and other vehicles weighing 10,001 pounds or more.

**Highway Cost Allocation Study (HCAS):** A study that estimates and compares the costs imposed and the revenues paid by different classes of vehicles over some time period.

**Highway Performance Monitoring System (HPMS):** The Federal Highway Administration collects and reports data about a sample of road segments in every state in a common format.

**Highway User:** A person responsible for the operation of a motor vehicle in use on highways, roads, and streets. In the case of passenger vehicles, the users are the people in the vehicles. In the case of goods-transporting trucks, the user is the entity transporting the goods.

**Incremental Cost:** The additional costs associated with building a facility to handle an additional, heavier (or larger) class of vehicle.

**Incremental Method:** A method of assigning responsibility for highway costs by comparing the costs of constructing and maintaining facilities for the lightest class of vehicles only and for each increment of larger and heavier vehicles. Under this method, vehicles share the incremental cost of a facility designed to accommodate that class as well as the cost of each lower increment.

**Light (or Basic) Vehicles:** The lightest vehicle class, usually including passenger cars. In Oregon, the current definition of Light Vehicles includes vehicles up to 10,000 pounds, which account for more than 90 percent of the total vehicle miles of travel on Oregon roads.

**Live Load:** The additional load on a structure by traffic (beyond the load imposed by holding itself up).

**Load-Related Costs:** Costs that vary with the load imposed by traffic on a facility.

**Marginal Cost:** The increase in total cost that results from producing one additional unit of output. With respect to highway use, the marginal cost is the increase in total highway costs that results from one additional vehicle trip. Economic efficiency is achieved when the price charged to the user is equal to the marginal cost.

**National Highway System (NHS):** A set of highways throughout the United States that have been designated as National Highways by the federal government. The Federal Highway Administration sets design and maintenance standards and provides funding for national highways, but the highways are owned by the states.

**National Pavement Cost Model (NAPCOM):** A model of pavement costs that incorporates the wear-and-tear costs imposed by vehicle traffic of different weights and configurations as well as deterioration from age and environmental factors, taking into account the soil type, road base depth, pavement material, pavement thickness, and climate zone.

**Non-Divisible Load:** Large pieces of equipment or materials that cannot be feasibly divided into smaller individual shipments. All states issue special permits for non-divisible loads that would otherwise violate state and federal gross vehicle weight, axle weight, and bridge formula limits.

**Operating Weight:** The actual weight of a vehicle at a particular time.

**Overhead Costs:** Costs that vary in proportion to the overall level of construction and maintenance activities but are not directly associated with specific projects.

**Passenger Car Equivalent (PCE):** A measure of road space effectively occupied by a vehicle of a given type under given terrain, vehicle mix, road type, and congestion conditions. The reference unit is the standard passenger car operating under the conditions on the road category in question.

**Registered Weight:** The weight that determines the registration fee paid by a single-unit truck or a tractor. For a tractor, it is typically the highest of that vehicle's declared weights.

**Revenue Attribution:** The process of associating revenue amounts with the classes of vehicles that produce the revenues.

**Right of Way:** The strip of land, property, or interest therein, over which a highway or roadway is built.

**Road Use Assessment Fee:** In Oregon, vehicles carrying non-divisible loads over 98,000 pounds on special permit pay a fee based on the number of ESAL-miles for the trip (see Equivalent Single-Axle Load).

**Social (or Indirect) Costs:** Costs that highway users impose on other users or on non-users. Costs typically included in this category are those associated with noise, air and water pollution, traffic congestion, and injury and property damage due to traffic accidents.

**Span:** A section of a bridge.

**State Highway System:** Roads under the jurisdiction of the Oregon Department of Transportation.

**Studded Tire:** A tire with metal studs imbedded in its tread for better traction on icy roads.

**Tax Avoidance:** The legal avoidance of a tax or fee.

**Tax Evasion:** The illegal failure to pay a tax or fee.

**Truck:** A general term denoting a motor vehicle designed for transportation of goods. The term includes single-unit trucks and truck combinations.

**User Charge:** A fee, tax, or charge that is imposed on facility users as a condition of usage.

**User Revenues:** Highway revenues raised through the imposition of user charges or fees.

**Value Pricing:** Prices set in proportion to the benefits received, rather than the cost of production.

**Vehicle Class:** Any grouping of vehicles having similar characteristics for cost allocation, taxation, or other purposes. The number of vehicle classes used in a cost responsibility (allocation) study will depend on the needs, purpose, and resources of the study. Since the Oregon weight-mile tax rates are graduated in 2,000-pound increments, the Oregon studies have traditionally divided heavy vehicles into 2,000-pound gross weight classes. Light (basic) vehicles are considered as one class in the Oregon studies. Potential distinguishing characteristics include weight, size, number of axles, type of fuel, time of operation, and place of operation.

**Vehicle Miles of Travel (VMT):** The sum over vehicles of the number of miles each vehicle travels within a time period.

**Vehicle Registration Fees:** Fees charged for being allowed to operate a vehicle on public roads.

**Weight-Mile Tax:** In Oregon, commercial vehicles over 26,000 pounds pay a user fee based on the number of miles traveled on public roads within Oregon. The per-mile rate is based on the declared weight of the vehicle, and for vehicles weighing over 80,000 pounds, the number of axles. Vehicles paying the weight-mile tax are exempt from the use-fuel (diesel) tax.

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# Appendix B1: Issue Paper

Efficient Fee

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# I. SUMMARY

## I.1 BACKGROUND

In the 2001 Oregon Highway Cost Allocation Study, the concept of efficient fee-based cost allocation was introduced. Instead of estimating costs imposed by forecasting highway-agency expenditures and then allocating those expected expenditures to vehicle weight classes, the efficient fee approach forecasts the revenues that vehicles in each weight class would pay if a set of revenue instruments were to charge each vehicle for the costs it imposes for each mile it travels, given the time and place of travel and the weight and other characteristics of the vehicle.

As is emphasized in the previous work on efficient fees for the Oregon Highway Cost Allocation Study, an efficient vehicle fee is about more than just paying for new infrastructure. An efficient fee recovers costs from users directly. Those costs relate to the maintenance and operation of existing infrastructure and services, new infrastructure needs that result from growing transportation demand, and even the costs of pollution.

This issue paper addresses how Oregon might go about demonstrating a program to convert its Highway Fund revenue instruments to efficient fee instruments. The state of Oregon has considerable history with the implementation of road use charging demonstration programs. The current status of the Road Usage Charge Pilot Program, and the history of related efforts are summarized in the ODOT report *Road Usage Charge Pilot Program 2013 & Per-Mile*

*Charge Policy in Oregon*. Another important effort with which the authors are deeply familiar is the *Traffic Choices Study* (a variable rate road charging trial) conducted in Seattle, WA in 2006. Together these two efforts constitute significant “local” knowledge regarding how to effectively design and implement road charging pilot projects.

## I.2 WHY CONSIDER AN EFFICIENT (VARIABLE) FEE

Variable pricing, based on peak periods of use, is a common form of pricing in other industries. It is used when capacity is fixed in the short-run, and demand fluctuates significantly between the peak and off-peak periods. Before cell phones, phone companies used peak-period pricing to encourage consumers to shift their use of the fixed capacity of the phone system to off-peak hours (e.g., by charging lower rates evenings and weekends). Some energy utilities use peak pricing. So do theaters. Economists recommend congestion pricing of roads for the same reason private firms use peak-period pricing: to use available resources more efficiently.

How would such pricing work for roads? Imagine that the vehicle you drive could tell a computer what road it is on, and at what time.<sup>1</sup> Location and time correlate to the amount of congestion and delay you are experiencing. Higher (variable) prices during peak periods would encourage you, or travelers with less pressing needs, to shift to other routes or times. That system has many advantages. By charging selectively at certain locations and times, one can influence the amount of congestion during peak periods. Variable tolling could reduce

the immediate need for building new highway capacity. By knowing where people are willing to pay tolls, planners would have a direct measure of where to build more capacity: namely, where drivers are willing to pay high tolls because the travel is so important to them. When those signals suggested that new capacity would be beneficial, the accumulated toll revenues would provide money to pay for those improvements. Fairness could also be improved, as revenue is collected from those who burden capacity directly.

The current transportation system is financed through a combination of use-related taxes and fees, and broad taxing instruments that have little relationship with transportation system use. Most existing use-fees are scaled to recover some set of costs by applying an average charge to all similar users. The fuel tax is an example where the cost to the consumer of fuel is an average cost tax on fuel by volume.

But in reality, the costs imposed by users vary considerably over time and space. The premise of congestion-based tolling (also called peak-period or variable pricing or tolling) is that this incorrect pricing leads to an over-consumption of certain types of transportation services (i.e., congestion) and an under-consumption of other transportation services. Correct pricing can reduce this problem. Conventional road finance exacerbates rather than ameliorates the problem. A low charge on all mileage allows excessive congestion during peak periods.

While the congestion prompts road authorities to build new capacity, the low charges cannot cover the costs.

<sup>1</sup>It should be noted that variable pricing does not necessarily involve tolls that dynamically respond to road conditions within very short time intervals. Variable toll rates can be time varying according to a set schedule so that road users have certainty about the costs they will encounter.

If financing of highways through road use charges is to become a more generally usable approach it would need to be responsive to a dynamic set of performance and investment conditions:

- Tolls are levied on existing capacity based on the costs the user imposes. As vehicle use in a corridor increases so do the toll rates; which manages growth in congestion.
- Revenues accrue over time and capacity is added where and when revenues are sufficient to justify investments.
- Cost-based toll rates can be lower after capacity is added since the tolls are not designed to meet a revenue target.
- Alternative routes also have cost-based tolls and so diversion is minimized and revenue yield is easier to predict.
- The entire enterprise is a sound platform for long-term investment and growth.

### **I.3 OPPORTUNITY FOR GAINS, BUT QUESTIONS REMAIN**

The promise of an efficient road use fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery, fairness, and pollution and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better asset management practices amongst road authorities.

The potential for gains is considerable. An estimate was developed of the benefits from implementation based on generalization of results from the Traffic Choices Study in Seattle. The direct benefits to transportation system users that result from a network application of road pricing are sizable, and dominated by the value of travel time-savings benefits. These are an estimate of the social welfare, or “efficiency”, benefits associated with the correct pricing of congested roads.

The estimate for the present value of the time-savings benefits is well over \$36 billion, with total implementation and operating costs of approximately \$5.5 billion. The net present value (benefits less costs) of the benefits to society from implementation of this network wide scenario of road pricing is estimated in the range of \$28 billion. Over the implementation period for this scenario the present value of toll revenues is estimated at \$87 billion.

Even as long-term benefits from an efficient fee program are clear and large in scale the challenges in implementing such a program are many. Such a fee program represents a large-scale change from existing policy and would involve disruptive transformation for many aspects of surface transportation management and operations.

#### **I.3.1 How will driving behavior change**

One of the most important questions a variable fee demonstration project can address is how drivers will respond to the fee structure. The many efficiency arguments in favor of variable road charges depend upon driver’s abilities to substitute lower cost (in terms of social costs of

congestion and otherwise burdening the road system) behavior for higher cost behavior. The theory is strong and supported by considerable empirical results but understanding details of driver response is important for designing systems that best meet consumer and road operator needs.

#### **I.3.2 What about the technology?**

Other questions relate to the technology that would be needed to support the program. Choosing a technology that must endure into the future is a challenging exercise. Many efforts to procure technical systems for demanding enterprises focus on functional requirements rather than technical specifications. This allows managing organizations to be clear about their needs without dictating specific technical details to the market for technical solutions. This was the general approach taken the Traffic Choices Study in Seattle (a smaller-scale pilot effort) and was also generally employed in the case of the Oregon Road Usage Charge Program (a larger-scale early voluntary opt-in implementation). Some specific technical aspects of a fee system operation are discussed in more detail later in this paper.

#### **I.3.3 How might privacy be addressed?**

Information systems are becoming increasingly complex. As information is collected, stored and used in more and more beneficial ways, there are also increasing concerns over how information that might be considered “private” is managed and protected against malicious use. Road tolling systems with automated

tolling transactions that associate the use of roads with an account holder are just one aspect of life that raise issues of privacy protection in the minds of consumers. A road tolling system that collects and stores detailed information about a large extent of the roads visited by all road users is by extension a larger source of the same kinds of concerns.

The fact is that a road tolling system, like the one that might be used in the operation of this demonstration, collects extensive and detailed information about individual users and their travel behavior. It is impossible to imagine such a system being put into operation without significant safeguards in place to secure personal information. There are many ways to protect the privacy of individuals and to inform them of what data are collected and how the tolling agency and its contractors will use them. With proper planning, education, and technology, the protection of privacy need not be a major roadblock to the successful implementation of congestion pricing systems.

#### **1.3.4 What about fairness?**

The primary arguments for road pricing are about improving efficiency and investment policy. Yet many people will wonder if improvements in efficiency will come at the expense of compromises in fairness. Whenever policies change, it creates potential winners and losers, and this would be no less true of congestion pricing of a region's roadways. Transportation services are central features of a regional economy. Consequently, a change in the pricing of highway services will have a mixture of good and bad impacts on certain

types of travelers, and on businesses and residents in subareas of the region.

Prospectively judging the fairness of a policy is complex at best, is subjective, and involves considerable uncertainty. Yet potential issues around the distribution of costs and benefits cannot simply be ignored.

Implementing congestion pricing means travelers using congested facilities during the peak period will face greater out-of-pocket costs than they currently pay through the gasoline tax alone. Off peak and night charges, on the other hand likely could be less than they are without congestion pricing if pricing were implemented broadly enough to permit average gasoline taxes to be reduced or eliminated.

#### **1.4 BUILDING ON CURRENT EFFORTS**

Oregon is currently implementing a Road Usage Charge Pilot Program; which will provide essential insights into many important topics relevant to the design and implementation of a variable rate pilot project. The implementation of a variable rate pilot project needs to be distinct from the Road Usage Charge Pilot Program but also take advantage of opportunities to build on the systems and practice put in place to support that program. The goal should be to build on success but not interfere with, or complicate, the ongoing implementation of an operational program. The primary differences between variable fees and their flat rate cousins are the need to retain sufficient spatial and temporal details about vehicle use in order to structure a revenue collection program that implements the variable fee. Although early work on mileage

fees attempted to design options that would not require the use of vehicle positioning technology, it turns out that spatial details are needed in order to efficiently and accurately administer a simple flat rate fee program.

#### **1.4.1 Road Usage Charge Pilot**

An examination of the operating requirements for the Oregon Road Usage Charge Pilot Program reinforces this basic understanding. Both the System Requirements Specifications (2012) and the Open System Architecture Model (2012) clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics.

The significant advantage of this compatibility between the variable fees of an efficient fee system and the systems that are to be used for flat rate mileage fees are fairly obvious. A single back office and technical platform offers considerable cost savings with respect to both eventual revenue operations and for the implementation of pilot studies and trials.

Road management and surface transportation policy do not exist in isolation from other aspects of urban systems management. It is therefore important to consider an efficient road usage fee program in light of a range of other policy interests and objectives. Some of these are discussed in this paper, but all of these can be evaluated further as a result of a pilot project implementation.

### **1.4.2 State Land Use Objectives**

Computer simulations of comprehensive congestion pricing policy have demonstrated that a comprehensively-applied congestion pricing system can favor the CBD and major centers, and discourages diffused suburbanization of economic activity. However, such simulations are necessarily very abstract, and may or may not faithfully capture the real-world response to congestion pricing.

### **1.4.3 Oregon Sustainable Transportation Initiative and GHG goals**

An efficient road use fee is uniquely suited to support the major goals of the Oregon Sustainable Transportation Initiative. The reason is that an efficient fee for road use will have broad effects on how urban systems interact with each other. As a starting point an efficient fee addresses reoccurring congestion on major roadways. Less congestion results in travel time-savings that get capitalized in the broader economy. The production possibilities for the Oregon economy are thus improved. The improved performance of the urban road network also reduces greenhouse gas emissions as moderate speeds are maintained even during peak travel periods. In addition, as discussed above, an efficient transportation fee will influence the spatial pattern of the economy and naturally support more compact use of desirable urban land without resorting to regulatory approaches that can be overly prescriptive or crudely applied.

### **1.5 DEMONSTRATING AN EFFICIENT ROAD USE FEE**

To demonstrate the operation of an efficient road use fee it is envisioned that a group of participants will be recruited from the population of Oregon residents. These participants will have their vehicles equipped with mileage fee metering devices for the duration of the demonstration. Participants will drive normally during a baseline data collection period. This baseline period will establish the driving patterns for each household. During the experimental period of the demonstration project the participants will be exposed to the efficient fee. All the major operations aspects of an actual mileage fee will be implemented and tested including, the back office functions, payment processing, and customer services. Many of these functions are already in operation to support the Oregon Road Usage Charge program. Participating households will not be asked to pay the fee out of their own pockets, but they must also face an actual incentive to align their driving behavior with the hypothetical mileage fee charges. To accomplish this objective the project will provide participating households with a travel budget account out of which mileage fees will be deducted. The incentive is realized because participating households are allowed to keep whatever balance remains in their account at the end of the experimental period.

Such a demonstration allows for a rich evaluation of driver behavior, support the estimation of revenue yields from alternate mileage fee policies, tests the operations

of the set of systems design to support implementation, permits the examination of how local option taxes could get included in a mileage fee, and tests a range of important topics (e.g. privacy, equity) that relate to policy. A successful implementation of a demonstration project such as this adds considerably to the inventory of knowledge about mileage fee viability and design and should be of interest to a broad set of stakeholders and levels of governmental management. The technology being deployed for the Oregon Road Usage Charge Program meets all the basic requirements for a variable fee pilot program. Building on the implementation of the Road Usage Charge Program represents a prudent approach to planning for the technical systems of a variable rate fee program as these technical systems will be proven and improved as a result of an extensive trial implementation period.

#### **1.5.1 Technology and Experimental Design**

Standard practice in electronic tolling involves the use of relatively simple in-vehicle radio tags, or transponders (e.g., FasTrak or E-Z Pass). The radio tags contain a unique electronic signature that is communicated to roadside equipment as the equipped vehicle drives by. This electronic toll collection approach has been used successfully since it was first introduced in the late 1980s. An efficient road use fee program would require that vehicles be located in space and time so the fee can also vary across these dimensions. The technical implications of these requirements are discussed in the body of the paper.

The dominant feature of the proposed demonstration project is that it will make use of volunteer participants in order to test a full range of important aspects of an actual efficient road use fee implementation. This is in contrast to some kinds of technical demonstration that are intended to prove out new technical system, often involving test facilities and technicians and test professionals.

Demonstration projects that aim to understand consumer behavior must also adhere to scientific standards (experimental designs) that allow for useful analysis to be performed at the conclusion of the study operation.

### **1.5.2 Geography**

The geographic locus of an efficient fee pilot program would follow from the fee structure that is employed. As variable fees for road use by time of day and location will be a large component of the efficient fee, its demonstration will require a location that currently experiences some considerable congestion of the road system. Other factors that might influence the location of a demonstration include the budget available to cover a larger or smaller extent of the road network and its users. Budget for such a demonstration will be driven by participant costs (recruitment, management, equipment, and endowment) and will be somewhat linear with the number of participants. To the extent that sub categories of participants are to be examined independently the sample size requirements will increase which may limit the geographic extent of the experiment. Three aspects of geography are covered in the paper, mileage fee coverage, road network details, and the geography of participant recruitment.

### **1.5.3 Management and Budget**

A variable rate road fee pilot project will be a complex undertaking and require a strong operational partnership from key stakeholders. These key stakeholders include Metropolitan Planning Organizations, various departments of the State of Oregon (at a minimum ODOT but possibly including other departments responsible for revenue collection, vehicle licensing, and enforcement), and the Federal Highway Administration. It is also true that the operation of a variable fee demonstration will require the partnership to be extended to private vendors in order to get the best value from the program operation. The key to the effective management of vendor participation is a clear division of responsibilities that is guided by the particular strengths of each party.

The largest costs for an efficient fee pilot project are likely the costs to implement the technical systems that levy charges and collect behavioral data. Once again it is worth pointing out that building on the approaches taken for the Oregon Road Usage Charge Program can yield significant cost advantages over designing a system from the ground up. Other costs associated with a behavior experiment might include higher costs for participant management, funding travel endowment accounts (should this be included in the experimental design), and the costs of behavioral analysis at the conclusion of the pilot operations. When the Oregon Road Usage Charge Program is significantly underway it will be feasible to develop a more detailed estimate of the costs to implement a variable rate pilot.

Based on the implementation of the Traffic Choices Study in the central Puget Sound region, and other related projects (ODOT, Netherlands) it is possible to develop a preliminary sense of the implementation costs. A pilot project with a two-year duration and involving around 1000 participants might cost between \$3 million and \$4 million. There may be possibilities for cost savings, but it is unlikely that the project, as specified, could be done for as little as \$2 million. Similarly, these estimates are based on an actual study that is similar: they are unlikely to be more than 50% too low, so it is unlikely that the project would cost more than \$5 million.

### **1.6 NEXT STEPS**

A well-designed demonstration of variable fee is major undertaking technically, politically, and financially. This kind of effort progresses incrementally. This paper is one first step. The next step would be to build upon the success of current efforts to implement road usage charges in Oregon. Additional steps toward a practical implementation of a pilot project involve developing clear objectives, coordination with other entities and interests and securing the appropriate authorization and funding. These include:

1. Demonstrate variable rates by building on the success and technical implementation of the current mileage fee program
2. Develop a clear message that explains why a pilot project is useful
3. Include local governments and MPOs in planning

4. Secure authorization and funding
5. Ensure accountability with clear expectations about results

## 2. HIGHWAY FINANCE INNOVATION IN OREGON

In the 2001 Oregon Highway Cost Allocation Study, the concept of efficient fee-based cost allocation was introduced. Instead of estimating costs imposed by forecasting highway-agency expenditures and then allocating those expected expenditures to vehicle weight classes, the efficient fee approach forecasts the revenues that vehicles in each weight class would pay if a set of revenue instruments were to charge each vehicle for the costs it imposes for each mile it travels, given the time and place of travel and the weight and other characteristics of the vehicle. In 2011, an efficient fee study was conducted in parallel with the traditional study and the efficient fee approach was carried through in as much detail as possible, given the availability of relevant data.

This issue paper addresses how Oregon might go about demonstrating a program to convert its Highway Fund revenue instruments to efficient fee instruments. The state of Oregon has considerable history with the implementation of road use charging demonstration programs. The current status of the Road Usage Charge Pilot Program, and the history of related efforts is summarized in the ODOT report Road Usage Charge Pilot Program 2013 & Per-Mile Charge Policy in Oregon. Another important effort with which the authors are deeply familiar is the Traffic Choices Study (a variable rate road

charging trial) conducted in Seattle, WA in 2006. Together these two efforts constitute significant “local” knowledge regarding how to effectively design and implement road charging pilot projects.

### 2.1 SB 801

Senate Bill 810, passed by the 2013 Legislature, creates a program whereby up to 5,000 motor vehicles may volunteer to pay a per-mile road usage charge of 1.5 cents per mile and receive a refund of Oregon fuel taxes paid. The program will begin in July 2015.

Participants would break even if their vehicles averaged 20 miles per gallon (MPG), which is close to the light-vehicle fleet average in Oregon. Of the up to 5,000 participants, no more than 1,500 may be expected to average less than 17 MPG and no more than an additional 1,500 may be expected to average between 17 and 22 MPG. In other words, if there were 5,000 participants, at least 2,000 must be vehicles that would be expected to pay more under the per-mile charge.

Revenues from the per-mile road charge would be deposited in the Highway Fund and 30 percent would be distributed to counties and 20 percent to cities. These are the same proportions currently used to distribute fuel tax and other Highway Fund revenues to local governments.

The legislation does not specify the details of how the fee would be administered. ODOT and the Road User Fee Task Force establish methods for recording and reporting numbers of miles traveled on highways. At least one method must not use vehicle location technology.

Participants would be allowed to select a method from the approved list. ODOT also will establish reporting periods.

The legislation does require that participants’ privacy be protected. ODOT, its service providers, and their subcontractors will be prohibited from disclosing personally identifiable information except as required by valid court order. Location and daily metered use information must be destroyed within 30 days after payment processing or dispute resolution is completed unless the participant consents to longer retention. There also will provisions for dispute resolution and refunds.

### 2.2 2006 ODOT ROAD USE FEE EXPERIMENT

The program authorized by Senate Bill 810 will not be Oregon’s first. In April 2006, a smaller pilot program was launched. It included 285 vehicles, 299 drivers from 221 households, and two service stations in Portland and lasted for 12 months.

The pilot study used in-vehicle devices that used location data to determine whether the vehicle was in the Portland metropolitan area, which had a higher per-mile rate during peak periods. Location information wasn’t stored or reported. The devices interacted with equipment at the participating service stations to add the per-mile charges to the fuel bill and allow the removal of Oregon fuel taxes from the bill.

The study concluded that implementing a similar fee statewide would require \$32.8 million of startup capital expenditure for infrastructure, not including the devices in taxpayers’ vehicles.

The devices used in the pilot cost \$547 each, but a mass-produced device would cost far less. Annual operating costs for communication, administration, and enforcement were estimated at \$1.6 million.

The 2006 study concluded that:

- Paying at the pump works. Liquid-fuel vehicles need to visit the pump anyway, the pump is equipped to collect payment, the pump knows how much fuel tax to credit, and the on-board device and communicate the amount of the mileage fee to the pump. Other arrangements might work better for all-electric vehicles.
- A mileage fee could be phased in. It could be required for new vehicles and older vehicles could continue to pay the fuel tax.
- A mileage fee could integrate with the point-of-sale systems in place at gas stations and with the State's fuel tax collection system.
- Variable pricing options are viable. The pilot tested a very coarse two-zone system, which proved that geographic location can be used to determine the appropriate fee level without telling the State where the vehicle is traveling.
- Privacy can be protected. The only transmitted and centrally-stored data needed to assess mileage fees are vehicle identifier, miles by rate, and gallons purchased.
- The system would place minimum burden on businesses.
- The potential for evasion is minimal. Tampering with an on-board device would result in payment of the fuel tax.

- The cost to the State of implementation and administration could be low and the ongoing administrative cost would be comparable to the ongoing cost of administering the fuel tax.

### 2.3 FUTURE OF ROAD TOLLING PAPERS

ODOT commissioned a number of important papers on topics relating to the future of road tolling in the state of Oregon. These papers were developed over a number of months beginning in 2009 and also include a report on pricing proposals for the Portland region. The reports address such topics as the role of pricing to support greenhouse gas reductions, the geographic and situational constraint on tolling, the sufficiency of travel models to support tolling analysis, the evaluation of reliability benefits from tolling, the general economic appraisal approaches and methods for analyzing toll projects, and specific guidance on conduction benefit-cost analysis. These white papers and reports together address a broad range of issues relevant to the design and implementation of a variable rate road use pilot project. Specific references to select findings from these reports are included in other sections of this paper.

### 2.4 TRAFFIC CHOICES STUDY

Other related work has been conducted just north of Oregon in Washington State. In 2006, the Puget Sound Regional Council, the designated metropolitan planning organization for the Seattle, Washington area, conducted a pilot project to determine how travelers would change their behavior in response to variable charges for road use. The Traffic Choices

pilot project placed GPS-based tolling meters in approximately 500 cars belonging to 275 participating households. It observed detailed driving behavior before, during, and after tolls were charged for the use of major freeways and arterials in the Seattle area. Tolls were charged between mid-2005 and mid-2006. Participants were given account balances that would leave them with \$75 at the end of the study if they did not change their behavior. If they did change their behavior in response to the tolls, they would be as better off as if the tolls were paid from their own money, in addition to the \$75. Due to the significant overlap between the Traffic Choices Study and the characteristics of an efficient fee for road usage, the design of this study and its results are referenced and summarized throughout this paper.

## 3. WHY CONSIDER A VARIABLE FEE

### 3.1 LIMITATIONS OF A FLAT FEE

Most of the public revenue sources that help pay for the transportation system do not increase with increased system use. Signals about the cost of transportation at the time it is consumed given by the prices charged at the time of consumption are misleading. They do not give a message that decreases driving when roadway capacity is most compromised, and revenues to increase capacity are not forthcoming. As a result, vehicles exceed the capacity of many miles of roadways for several hours each day; in other words, the result is that use exceeds free-flow capacity, that demand exceeds supply, and that roads are congested.

The current transportation system is financed through a combination of use-related taxes and fees, and broad taxing instruments that have little relationship with transportation system use. Most existing use-fees are scaled to recover some set of costs by applying an average charge to all similar users. The fuel tax is an example where the cost to the consumer of fuel is an average cost tax on fuel by volume.

But in reality, the costs imposed by users vary considerably over time and space. Most important, the costs each new vehicle entering a crowded road during rush hour imposes on the existing stream of vehicles may be very high. The costs that same vehicle imposes on the operation of the system, and the other users on that same road at 11 o'clock at night, may be very low. The premise of congestion-based tolling (also called peak-period or variable pricing or tolling) is that this incorrect pricing leads to an over-consumption of certain types of transportation services (i.e., congestion) and an under-consumption of other transportation services. Correct pricing can reduce this problem.

Conventional road finance exacerbates rather than ameliorates the problem. A low charge on all mileage allows excessive congestion during peak periods. While the congestion prompts road authorities to build new capacity, the low charges cannot cover the costs.

Building a political coalition to raise the tax on fuels, or to increase a flat rate fee structure more generally, is difficult. Since congestion in urban areas prompts expensive capacity enhancing projects the low average fee for road use rarely

generates sufficient revenue to cover these costs at a local level. Likewise maintenance costs for low use rural roads may need supplemental funding other than what might be raised from a tax on fuels. This raises concerns over taxpayers in one jurisdiction playing for projects in other settings. Even when these concerns are unfounded the perception of this issue can be enough to thwart a political effort to increase road funding.

Currently there is considerable interest in replacing the tax on motor fuels with a flat rate mileage fee. Such a fee would address the problems of declining revenues associated with improvements in the fuel efficiency of the vehicle fleet but would still suffer from the many other limitations of a flat rate fee structure.

### **3.2 VARIABLE MILEAGE FEE CAN RAISE THE RIGHT AMOUNT OF REVENUE**

Variable pricing, based on peak periods of use, is a common form of pricing in other industries. It is used when capacity is fixed in the short-run, and demand fluctuates significantly between the peak and off-peak periods. Before cell phones, phone companies used peak-period pricing to encourage consumers to shift their use of the fixed capacity of the phone system to off-peak hours (e.g., by charging lower rates evenings and weekends). Some energy utilities use peak pricing. So do theaters. Economists recommend congestion pricing of roads for the same reason private firms use peak-period pricing: to use available resources more efficiently.

How would such pricing work for roads? Imagine that the vehicle you drive could tell a computer what road it is on, and at what time.

Location and time correlate to the amount of congestion and delay you are experiencing. Higher (variable) prices during peak periods would encourage you, or travelers with less pressing needs, to shift to other routes or times.

That system has many advantages. By charging selectively at certain locations and times, one can influence the amount of congestion during peak periods. Variable tolling could reduce the immediate need for building new highway capacity. By knowing where people are willing to pay tolls, planners would have a direct measure of where to build more capacity: namely, where drivers are willing to pay high tolls because the travel is so important to them. When those signals suggested that new capacity would be beneficial, the accumulated toll revenues would provide money to pay for those improvements. Fairness could also be improved, as revenue is collected from those who burden capacity directly.

Ideally, variable tolling would apply to all roads in a region, and efficient tolling would be based on costs that vary by volumes on the roadways, vehicle type, facility, and distance. Less comprehensively, it could be applied selectively to certain facilities or vehicle types (e.g., heavy vehicles). Either would be more efficient than current approaches to finance, which are a combination of semi-efficient pricing (fuel taxes, parking charges, mileage fees) and indirect charges (registration fee, general taxes, ramp metering).

Why would such a practice be more efficient? Within regions with relatively mature transportation systems, peak-period demand

also drives the need for new investments in roadway infrastructure. Urban transportation systems are sized and built primarily in response to peak-period use. If consumers (travelers) do not perceive the full costs their travel imposes on the system (reasons to be provided shortly), they will consume too many trips. Peak trips are incorrectly (non-optimally) priced, and the price distortions lead to increased cost to the region in the form of congestion delay and wasted resources. Where traffic conditions are unstable (high vehicle densities) the delay imposed on subsequent vehicles from added vehicles can be quite high and can continue to be experienced long after the vehicle in question has exited the congested segment of roadway.

If individual drivers were to be made responsible for the actual costs that their travel decision imposes on society some drivers might not make the same travel decision as when they experience only the average variable costs of travel (their own travel time). The essence of congestion pricing of roads is that drivers should pay for the aggregate delay they impose on other drivers. If they are not asked to pay these costs, they will each make travel decisions that collectively result in a lot of lost time for all travelers.

The benefits of road pricing are the reduction in social costs in the form of higher speeds/less travel time. The toll revenues are a transfer from road users to the system operator. It is generally the case that the toll revenues are larger than the user benefits, implying that road users (as a general class) will be made worse off under

road pricing unless the revenues are used wisely and in a manner that benefits those who pay the tolls.

To understand why peak-period tolling can yield savings, it is necessary to understand the role of pricing in rationing capacity costs. Consider the case, for example, of a movie theater operator deciding how much seating capacity to build in his theaters. The market for theater tickets exhibits wide swings in demand (not unlike a freeway); if the theater owner builds to fully accommodate the peak demand, he runs the risk that he will have a glut of capacity most of the time: capacity he often cannot sell to recover costs. Conversely, if he builds only to accommodate the off-peak demand, then he will have problems of too little capacity in the peak, leading to queuing by customers (“congestion”) and lost revenues. In either case, the company’s resources or the customers’ resources (or both) are wasted.

The solution is to allocate the costs of the capacity to those customers who require it (and are willing to pay for it) by charging more during peak periods than off-peak periods. This strategy rations the expensive, peak capacity, making sure it is not overwhelmed by users who are unwilling to pay, while generating the extra revenue needed to defray the costs of the extra capacity that the company has built to accommodate these customers. In addition, charging peak prices makes it easier for the company to determine how much capacity to build over time based on whatever the peak-period customers are willing to pay.

### **3.3 VARIABLE FEES REDUCE CONGESTION, WHILE RAISING NEEDED REVENUE**

Highway authorities may worry that the short run pricing perspective will not address the issue of how to pay for the investment in the roadway itself. In fact, however, if road pricing and investment policies are managed correctly, congestion charges will generate enough revenue to finance capacity throughout time. The logic of this conclusion is important, and worth elaborating upon. The key point is that pricing and investment are both focused on balancing user costs and benefits. The congestion and wear-and-tear increments of short-run prices actually do indicate the value of new or improved capacity:

If the congestion component of short-run prices is high, it is because traffic delays are great and added capacity (which would relieve the congestion) is more likely to be cost-beneficial. Similarly, if the wear-and-tear costs are high, it is because the roadway is vulnerable to traffic loads and, hence, a project to improve the road’s durability would be more likely to be cost-beneficial.

Investment policy itself balances these benefits against the cost of developing the facility. In this manner, congestion tolls and road building costs are related when tolling is properly integrated with decisions to build new roads. Roadways should be improved as long as the cost of serving additional vehicles with the improved road is less than the cost involved in serving them on the existing roads (indicated by the congestion price). Congestion tolling dovetails with a benefit-cost based approach to highway investment decision-making.

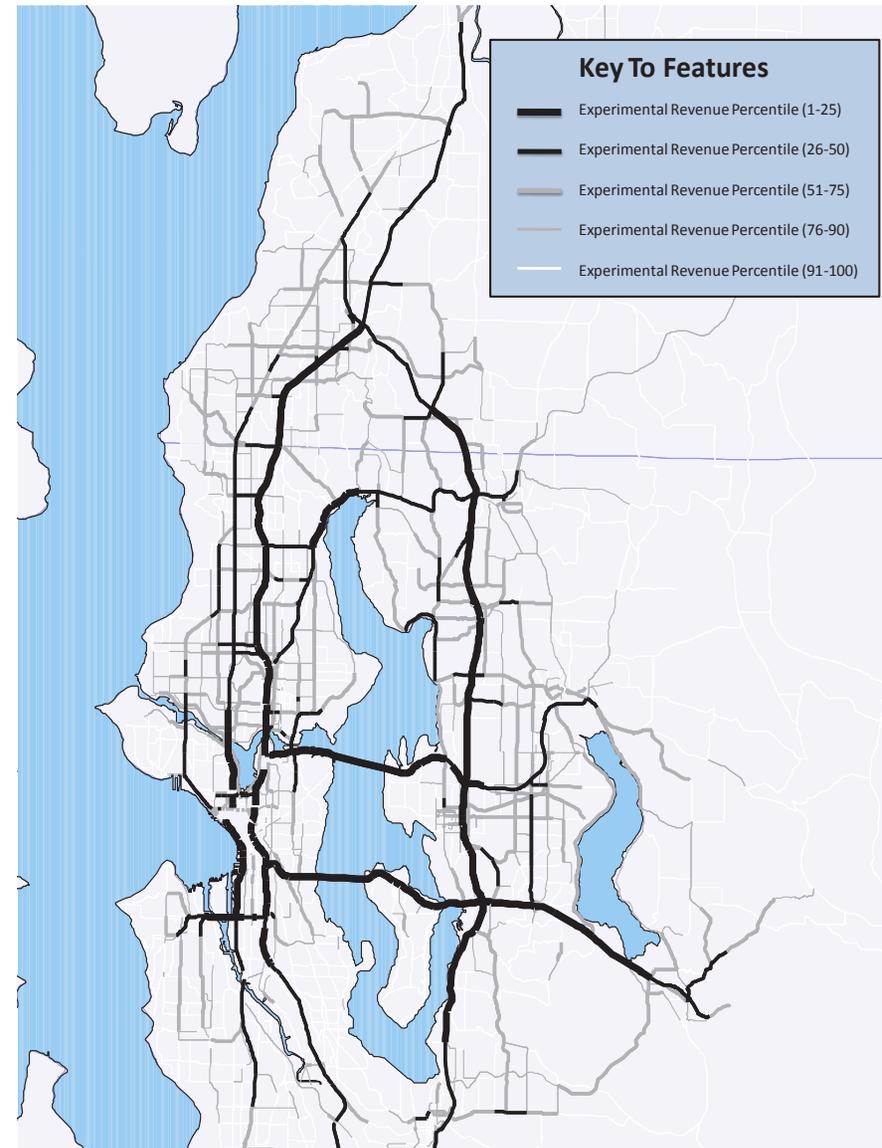
Tolling existing roads with appropriate efficient fees makes it easier to identify the road segments that are candidates for improvement: those on which the congestion prices are high, relative to the cost of defraying roadway improvements in that corridor. And congestion prices help moderate congestion in the first instance, and reduce the “false” signals sent by unpriced, congested roads.

The Traffic Choices Study in Seattle offers an opportunity to better understand these phenomena. With 275 households paying road tolls every time they used individual roads in the central Puget Sound region, it was possible to gain some insight into which roads users are willing to pay to use. Since the Traffic Choices Study offered the participants the opportunity to retain funds for avoiding the highest demand facilities that were their preferred choices, those facilities that generated the most revenues represent a truly high value service. The 275 households paid over \$275,000 in road tolls during the 10 months of toll operations. Just over 5 percent of the tolled road network (centerline miles) generated 50 percent of the toll system revenues ([Exhibit 3.1](#)).

During peak driving times it is no surprise that key multi-lane limited access facilities carried the largest volumes of traffic, and as a result generate sizable revenues when operated as toll roads. These same facilities, designed for high speeds under less than capacity loadings, are notably congestible when demand is high. While a few roads generated half of the toll revenues during the course of the study, the other half of the revenues were generated on a larger number of secondary roads distributed throughout the core urban network. This has at least two important implications for any system of toll roads that focus on the limited-access facilities; 1) failing to include secondary roads in the tolling network represents a sizable loss of revenue opportunity, and 2) of arguably greater importance, failing to appropriately toll the secondary roads will result in traffic diversion onto those roads and result in a loss of revenue and significant degradation of service quality. Traffic diversion may be a particularly onerous problem in environments (such as the greater Portland region) where bus transit systems move large numbers of people during peak travel hours using the secondary road network.

At some point, of course, as new capacity is added to an under-built roadway, the spillover costs (and thus the appropriate congestion price) are reduced, so it becomes cheaper to serve travelers without additional improvements. Thus, the theoretical decision rule is that roadways should be improved until

**Exhibit 3.1. Toll Revenues From Traffic Choices Study by Facility**



Source: Puget Sound Regional Council, ECONorthwest

the congestion price is equal to the incremental improvement costs. On a roadway that is neither under-built nor overbuilt, the price calculated from the construction and operating cost of new capacity or from the congestion penalty are the same.

Batten and Pozdena demonstrated this empirically for the state of Oregon in 2000 as part of the Oregon Highway Cost Allocation Study (HCAS) process. They emulated efficient tolling statewide, using available data on roadway utilization to project loads and associated tolls for the entire, State system. For the State system as a whole, total revenues collected were not vastly larger under efficient tolling. This suggests that (a) the system, as a whole, is not significantly underbuilt and (b) reform of tolling could occur without imposing toll costs that are, in the aggregate, very different from the current fuel tax, weight mile and registration fees levied today.

In the absence of road pricing, the use-based revenues to road authorities are generally not sufficient to support the kind of infrastructure investment agendas that are a product of the political process. As such, infrastructure investments are underwritten by general taxes. Under these circumstances, travel delay due to congestion becomes the limiting factor that brings the market into some kind of balance. The consequences of this inefficient equilibrium in terms of lost resources are significant.

If financing of highways through road use charges is to become a more generally usable approach it would need to be responsive to a dynamic set of performance and investment conditions:

- Tolls are levied on existing capacity based on the costs the user imposes. As vehicle use in a corridor increases so do the toll rates; which manages growth in congestion.
- Revenues accrue over time and capacity is added where and when revenues are sufficient to justify investments.
- Cost-based toll rates can be lower after capacity is added since the tolls are not designed to meet a revenue target.
- Alternative routes also have cost-based tolls and so diversion is minimized and revenue yield is easier to predict.
- The entire enterprise is a sound platform for long-term investment and growth.

### 3.4 VARIABLE FEES REDUCE THE “NEED” FOR EXPENSIVE CAPACITY IN URBAN AREAS

In the absence of road pricing, the incremental revenues to road authorities (government) are not sufficient to support the kind of infrastructure investment agendas that are a product of the political process. As such, infrastructure investments are subsidized by general taxes, reinforcing inappropriate pricing, which signals leading to user demand exceeding supply (congestion). Under these circumstances, travel delay due to congestion becomes the limiting factor that brings the market into some kind of equilibrium. The consequences of this inefficient equilibrium are significant. The European Conference of Ministers of Transport published a research report entitled *Assessing the Benefits of Transport*<sup>2</sup> in 2001. An excerpt from the executive summary of this report reads as follows:

*Depending on the circumstances, there can be a net extra benefit from the wider economic effects, which therefore will strengthen the case for an infrastructure investment (road, rail or other, according to local conditions), provided it actually delivers its promised improvements in costs, speeds etc. In other conditions, however, wider economic benefits may be more effectively achieved by transport initiatives other than infrastructure investment (for example traffic management, infrastructure pricing, etc.). In general, where there are distortions in pricing, it is better to correct the prices than to develop investment projects based on the existing prices.*

In short, optimal investment procedures involve benefit-cost assessments in which all appropriate marginal costs and benefits of an investment are counted. A properly specified benefit cost analysis provides useful information about the potential societal gains associated with undertaking the transportation investment. Ideally, all cost-beneficial investments are implemented that are affordable, within some reasonable budget constraint. Investments that are not established to be cost beneficial would not be implemented unless some other overriding policy objective, not accounted for in the benefits analysis, is realized. In which case, the reason for making an otherwise low benefit investment would be explicitly understood by everyone involved in the decision process.

If congestion under unpriced conditions is the wrong signal for investment then implementing variable fees for road use must by definition reduce this costly congestion even in the absence of new road investments.

<sup>2</sup><http://internationaltransportforum.org/europe/ecmt/pubpdf/01Benefits.pdf>

Experiments and real world application of congestion-based fees have demonstrated this to be true. As is stated above, the new revenue will be a much better investment signal than congestion levels on the roadways – and investments will be justified. What is likely is that the investments in new road capacity that are justified will be in smaller increments and at later points in time than would otherwise be the case absent variable road use charges. Smaller increments of investment and the ability to implement these investments later represent real resource cost savings for the state of Oregon.

**3.5 LONG-RUN: BENEFITS OF VARIABLE COST-BASED FEES ARE HIGH**

The promise of an efficient road use fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery, fairness, and pollution and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better asset management practices amongst road authorities.

The potential for gains is considerable. An estimate was developed of the benefits from implementation based on generalization of results from the Traffic Choices Study in Seattle. The direct benefits to transportation system users that result from a network application of road pricing are sizable, and dominated by the value of travel time savings benefits. These are an estimate of the social welfare, or “efficiency”,

benefits associated with the correct pricing of congested roads.

Exhibit 3.2 displays the benefit and cost findings from this analysis as well as the value of the toll transfer. The present value of the time savings benefits is well over \$36 billion, with total implementation and operating costs of approximately \$5.5 billion. The net present value (benefits less costs) of the benefits to society from implementation of this network wide scenario of road pricing is estimated in the range of \$28 billion. Over the implementation period for this scenario the present value of toll revenues is estimated at \$87 billion.

The direct benefits to transportation system users are sizable, and dominated by the value of travel time benefits. These are an estimate of the welfare, or “efficiency”, benefits associated with the correct pricing of congested roads. While the experiment was an approximation of optimal pricing policy, a number of important observations can still be made.

First, those who benefit most from network tolling are users with high values of time (higher income motorists and trucks). Transit users and occupants of high occupancy vehicles all realize benefits from tolling as well. Second, the toll revenues that result are considerably larger than the direct user benefits. This is to be expected, but emphasizes the importance of using those revenues to provide further benefits to the road system users. The third point follows from the second: this analysis makes no assumptions about the use of those revenues; which might be used to make improvements to the transportation system (leading to further

**Exhibit 3.2. Benefits and Costs of Network Road Pricing**

Present Value Benefits/Costs	Millions of 2008 Dollars
<b>Benefits</b>	
Time Savings	\$36,600
Reliability Benefits	\$4,500
Operating Cost Savings	\$2,500
Toll Effects on Consumer Surplus	-\$97,100
System Operator Benefits (Tolls)	\$87,000
<b>Present Value of Benefits</b>	<b>\$33,600</b>
<b>Costs</b>	
OBU Costs	\$1,500
Enforcement	\$100
Central System	\$500
Data Communication	\$3,300
Other	\$100
<b>Present Value of Costs</b>	<b>\$5,500</b>
<b>Present Value of Benefits less Costs</b>	<b>\$28,200</b>
<b>Benefit-to-Cost Ratio</b>	<b>6.1</b>

Source: Puget Sound Regional Council, ECONorthwest

user benefits) or to offset other taxes and fees (a transfer directly back to the users that also eliminates welfare losses associated with the taxes and fees).

The revenues from network road tolling, in this analysis, are in excess of \$13 million (year 2008 dollars) per average weekday. Once again, these may not be optimal toll rates, where the rates that result in the greatest net benefits to society may generate either higher or lower revenues than those analyzed here. Based on 260 weekdays of tolling; the scenario results in more than \$3.4 billion in gross annual revenues. As a comparison, all the transportation agencies in the central Puget Sound region collected approximately \$3.1 billion in transportation related revenues (revenues used for transportation expenditures) in 2005.

Absent the rationing of supply based on willingness-to-pay (tolling), it is very difficult to gauge the ideal level of investment in transportation supply. But it appears that network tolling revenues are sufficient to replace all non-use fee forms of transportation revenues currently used to invest in the road system, and would still leave considerable revenues left over for road improvements, and the support of transit or other service operations on the road network.

The user benefits are large, but the toll revenues that result are considerably larger. This is to be expected, but emphasizes the importance of using those revenues to provide further benefits to the road system users through reinvestment, or rebating other taxes and fees.

Congestion-based tolling generates revenues for investment but also limits the wasted time resources associated with overconsumption of scarce peak period roadway capacity. So, a full accounting of the costs and benefits of road tolling compares the implementation and operating costs of the program with the full benefits of more efficiently allocating road space resources. The tolling revenues themselves are treated as an economic transfer since the revenues represent a cost to road users and a benefit to the toll system operator. In the case of public sector management of a tolling system, the revenues could be expected to be reinvested in the transportation system or used to offset other taxes and fees that support public investments.

Under the implementation scenario outlined above, the tolls paid by users and collected by the operator exceed the value of the user

benefits. This is expected under all but the most congested pre-tolling road network conditions. If toll revenues are somehow squandered, the effects on society from road tolling will be negative. This finding reinforces the general conclusion that it is not productive to discuss road tolling without simultaneously addressing the issue of how toll revenues will be used.

## 4. STILL TOO MANY QUESTIONS TO ADDRESS

Even as long-term benefits from an efficient fee program are clear and large in scale the challenges in implementing such a program are many. Such a fee program represents a large-scale change from existing policy and would involve disruptive transformation for many aspects of surface transportation management and operations. Some of these topics are discussed below.

### 4.1 HOW DRIVERS WILL RESPOND TO ALTERNATIVE FEE STRUCTURES

One of the most important questions a variable fee demonstration project can address is how drivers will respond to the fee structure. The many efficiency arguments in favor of variable road charges depend upon driver's abilities to substitute lower cost (in terms of social costs of congestion and otherwise burdening the road system) behavior for higher cost behavior. The theory is strong and supported by considerable empirical results but understanding details of driver response is important for designing systems that best meet consumer and road operator needs.

#### 4.1.1 Price Elasticities

The literature on how tolls influence driver behavior is quite large, and estimates of price elasticities (percent change in a measure of demand as a ratio of percent change in price or toll costs) vary based on specific circumstances and the timeframe over which behavior is observed.

The Traffic Choices Study in Seattle was possibly the largest scale controlled experiment of tolls being applied to an entire regional network. Elasticities from this study are a useful starting point for understanding the behavioral response of drivers.

The Traffic Choices Study provides the best currently available measures of actual consumer behavior change in response to region-wide variable congestion pricing. Across all households and all trip purposes, the following changes were observed:

- 7 percent reduction in all vehicle tours (tours per week)
- 12 percent reduction in vehicle miles traveled (miles per week)
- 8 percent reduction in tour drive time (minutes of driving per week)
- 6 percent reduction in tour segments (segments of tours per week)
- 13 percent reduction in miles driven on tolled roads (tolled miles per week)

Household elasticities of demand with respect to vehicle operating costs were in the range of -0.05 to -0.15 and are consistent with other empirical estimates. In the economics this

range of response is termed inelastic meaning the change in demand is less in percentage terms than the change in prices. And while travel demand is generally understood to be inelastic this should not be interpreted as there being only a modest opportunity to improve the efficiency of the system. To the contrary, the behavioral response to prices for road use are consistently observed and the magnitude of changes in traffic conditions can often mean the difference between a breakdown in the performance of high use roads and free flowing traffic. A more detailed discussion of the analysis and findings from the Traffic Choices Study data can be found in Appendix B1-A.

#### **4.1.2 Traffic Diversion**

A potential concern with road tolls involves the amount of traffic that avoids paying tolls by driving on secondary facilities, or diversion. These concerns were evident in the analysis of toll road projects (NW Cornelius Pass Road and Oregon Highway 217) that were part of ODOT's congestion pricing study resulting from HB 2001. In these cases the projects being evaluated even performed poorly in terms of financial viability due to the toll policies and prevalence of attractive diversion routes. Technically diversion can involve traffic on secondary roads but also can involve trips diverted off the tolled road and made by another mode, or even time of day in the case of time varying toll rates. An important feature of an efficient road fee is that the fee applies to secondary roads as well. One aspect of a demonstration project is to better understand how fees could get structured and managed over time in order to minimize diverted traffic. For example in Germany the

heavy vehicle fee program has added roads to their charging network over time as these roads experience increased in traffic and congestion. And since an efficient fee is one that mirrors peak traffic flows the worst kind of traffic diversion, diversion from overpriced and underutilized toll roads during off peak driving periods, is avoided altogether.

#### **4.1.3 Response Surface Over Time**

Most estimates of driver response to tolls (including those developed from the Traffic Choices Study) are short-run in nature. In the short-run the opportunities for drivers to avoid tolls may be limited while in the long-run substituting toward lower cost behavior is often more feasible. For example in the short-run past decisions regarding home and work locations will be fixed and in the long-run these decisions can take an efficient road use fee structure into account. As a result it is generally agreed that long-run elasticities of demand are higher in magnitude than are short-run estimates.

#### **4.1.4 Compliance/Evasion**

Avoidance behavior is a factor in any program that recovers fees for use of an asset or service. There is an extensive literature on avoidance behavior in general and toll evasion in particular. Generally evasion (trying to evade paying the charge when the service has been rendered) will be a function to some dominant factors 1) the opportunity to engage in evasive behavior, 2) the cost of being caught engaged in evasive behavior, and 3) the probability of being caught. An additional factor is the risk tolerance of any given person with respect to being caught and having to pay the penalty.

The implication for an efficient road use fee program is that the general systems for ensuring compliance and enforcement must be carefully designed. Individual approaches to compliance and enforcement have various different cost associated with their implementation and operation, so a careful accounting of cost and revenue effects is needed in order to select an appropriate approach.

#### **4.2 WHICH TECHNOLOGIES WILL MEET THE REQUIREMENTS NOW AND IN THE FUTURE?**

Choosing a technology that must endure into the future is a challenging exercise. Many efforts to procure technical systems for demanding enterprises focus on functional requirements rather than technical specifications. This allows managing organizations to be clear about their needs without dictating specific technical details to the market for technical solutions. This was the general approach taken the Traffic Choices Study in Seattle (a smaller-scale pilot effort) and was also generally employed in the case of the Oregon Road Usage Charge Program (a larger-scale early voluntary opt-in implementation).

The toll industry is a highly dynamic industry with technical systems that mirror those employed by other information and communication intensive industries. The pace of new technology adoption is fast and the costs of locking into an inferior technology model can be high. These risks are low for a small-scale demonstration project but considerable for full operations. Some specific technical aspects of a fee system operation are discussed in more detail later in this paper.

### 4.3 HOW CAN PRIVACY CONCERNS BE HANDLED?

Information systems are becoming increasingly complex. As information is collected, stored and used in more and more beneficial ways, there are also increasing concerns over how information that might be considered “private” is managed and protected against malicious use. Road tolling systems with automated tolling transactions that associate the use of roads with an account holder are just one aspect of life that raise issues of privacy protection in the minds of consumers. A road tolling system that collects and stores detailed information about a large extent of the roads visited by all road users is by extension a larger source of the same kinds of concerns. The fact is that a road tolling system, like the one used in the operation of this experiment, collects extensive and detailed information about individual users and their travel behavior. It is impossible to imagine such a system being put into operation without significant safeguards in place to secure personal information. Appendix B1-B discusses privacy and road tolling in more detail.

The questions around privacy protections in part change with respect to the circumstances of the individual whose data requires protection. These circumstances include the following:

- **Normal Vehicle Operations** – what data is available to whom and under what circumstances in the case of users who are assumed to be in compliance with the fee program?
- **Suspicion of Fee Evasion** - what data is available to whom and under what

circumstances in the case of users who are assumed to be out of compliance with the fee program? And furthermore how is out of compliance determined in the first place?

- **Suspicion of Other Crimes** – what data is available to whom and under what circumstances in the case of users who are suspected of other crimes and where vehicle use data is considered relevant to a criminal investigation? Privacy is discussed in more detail in Appendix B1-B, but it is also useful to think of a pilot program as an opportunity to clarify privacy objectives and standards of practice.

Each of the technologies used for electronic tolling will record data on users’ personal travel behavior (if they use a toll road or enter a cordoned area), but the level of privacy concerns vary for each of the technologies. For example, while there is a general concern about theft of the in-vehicle devices or hacking of a user’s account, there are fewer concerns with the theft of transponders than with in-vehicle GPS devices, because transponders carry no record of where they’ve been. On the other hand, transponder-based systems need to store information about where the transponder has been read in a back-end data system, whereas GPS-based on-board units can keep all location data inside the unit, which remains in the user’s possession unless it needs to be audited.

Many consumers misunderstand how GPS works and believe that in GPS-based systems, satellites can “see” them and track them as they move around. In reality, the GPS satellites only transmit their identifier and the time. GPS

receivers use differences in time to calculate their distance to each satellite they can “see,” and from those, calculate their position on the surface of the earth. Acceptance of GPS-based technology will require educating consumers.

People also have privacy concerns related to the use of cameras for tolling. Many people are concerned with the use or sale of personal travel data to entities not directly related to tolling, such as law enforcement agencies, private investigators, or firms seeking to use the data for marketing purposes.

In Germany, the Federal Office for Goods Transport (BAG) is responsible for the truck toll system and Toll Collect is a subcontractor. BAG defines the requirements to be implemented and oversees the data protection policy. Permission to process data for the toll system is provided by the Truck Toll Regulation and the Federal Commissioner for Data Protection and Freedom of Information. Data is processed by the operator, “strictly in accordance with data protection guidelines and exclusively for the statutorily prescribed purpose of toll collection.” Personal data are transmitted only to the extent necessary to fulfill toll collection and contract obligations and the transmission of data is performed through authenticated encrypted messages. In addition, the bill itself only contains information about the route the truck traveled, at what time, and the toll the user is required to pay. Law enforcement authorities cannot use this information to determine average speed as the on-board unit does not store any information on the speed of the truck. Billing data are not sold to any third parties. The German system relies on photographs of

vehicles' license plates for enforcement; drivers cannot be recognized in the photos. Photos are deleted "within a fraction of a second" for vehicles that are determined to be exempt from the toll.

In the U.S., E-Z Pass customers are assured that all information related to their account, including their financial information and vehicle movement records, will only be used for billing, deducting toll charges, enforcing toll collection laws, or other legal uses as ordered by courts. The latter allowed use has caused some concern, however, as E-Z Pass records were released under court order and used in a divorce trial as evidence of infidelity.

There are many ways to protect the privacy of individuals and to inform them of what data are collected and how the tolling agency and its contractors will use them. With proper planning, education, and technology, the protection of privacy need not be a major roadblock to the successful implementation of congestion pricing systems.

Andrew J. Blumberg of Stanford University, along with several coauthors, has published extensively on location privacy in general and location privacy issues related to tolling in particular. Blumberg argues that systems that create and store digital records of people's movements through public space are an inextricable part of the fabric of everyday life and there will be many more such systems in the near future. He cites current examples such as:

- Monthly transit swipe-cards
- Electronic tolling devices (e.g., FasTrak, E-Z Pass)

- Cell phones
- Services telling you when your friends are nearby
- Searches for services and businesses near your current location
- Free Wi-Fi with ads for businesses near the network access point you're using
- Electronic swipe cards for doors
- Credit and debit card transactions at stores, ATMs, vending machines, etc.

He argues that these systems are innovative and promise benefits ranging from increased convenience to transformative new kinds of social interaction. Unfortunately, these systems pose a dramatic threat to location privacy, the ability of an individual to move in public space with the expectation that under normal circumstances there is no record of their having been there. Society is not likely to stop the cascade of new location-based digital services, nor does it appear that it would want to, as the benefits of such services to users are expected to be substantial.

#### **4.4 WINNERS AND LOSERS; EQUITY IN SEVERAL DIMENSIONS**

The primary arguments for road pricing are about improving efficiency and investment policy. Yet many people will wonder if improvements in efficiency will come at the expense of compromises in fairness. Whenever policies change, it creates potential winners and losers, and this would be no less true of congestion pricing of a region's roadways. Transportation services are central features of

a regional economy. Consequently, a change in the pricing of highway services will have a mixture of good and bad impacts on certain types of travelers, and on businesses and residents in subareas of the region.

Prospectively judging the fairness of a policy is complex at best, is subjective, and involves considerable uncertainty. Yet potential issues around the distribution of costs and benefits cannot simply be ignored. Yet, what does fairness depend on?

- Value of travel time savings (willingness to pay)
- Income effects ability to pay
- Availability of alternatives
- Uses of the revenues

Implementing congestion pricing means travelers using congested facilities during the peak period will face greater out-of-pocket costs than they currently pay through the gasoline tax alone. (Off peak and night charges, on the other hand likely could be less than they are without congestion pricing if pricing were implemented broadly enough to permit average gasoline taxes to be reduced, for example. Realistically, however, this would require a comprehensive tolling system.) This will cause some diversion of trips to different routes, at different times, by different modes, and may induce some travelers not to travel at all.

Because these adjustments in travel behavior relieve traffic levels on the priced roadway, the roadway offers faster and more reliable travel times to all vehicle types, which may benefit even those who are induced to change their

travel behavior. Gomez-Ibanez analyzed the application of congestion pricing to existing roads and identified the most important winners and losers.

There are several important things to note about any accounting of winners and losers. First, some travelers will benefit from congestion-based charging only if the HOV response is good. Those who are “tolled out” of their SOVs, for example, can benefit only if this is the case. This underscores the importance of removing the institutional impediments to increased bus, vanpool and carpool services. It may also argue for use of some of the congestion-based charging revenue to assist transit. Second, the pattern of winners and losers does not decompose directly into rich vs. poor, as is sometime alleged by critics of congestion pricing. Although drivers of SOVs with low time values are the ones most likely to be “tolled off” the road, many may be better off despite this if the performance of the highway-based HOV alternatives improves significantly. Those for whom HOV alternatives remain unsatisfactory, however, will be adversely affected.

Gomez-Ibanez identifies three groups that are likely to be winners:

1. Motorists who would drive with or without the toll but who place a high value on travel time savings (for these motorists the gains from improved traffic speeds outweigh the toll cost);
2. Travelers who would use HOV services on the tolled road whether or not tolls are charged (they benefit from improved speeds while paying little or no toll); and

3. Recipients of toll revenues (i.e., taxpayers if tolls reduce the pressure for tax increases or, alternatively, the clients of government programs if tolls are used to finance an expansion of government services).

Four other groups are likely losers.

1. Motorists who would continue to drive on the road despite the toll but who place a relatively low value on travel time. (Even though the time savings does not compensate these motorists for the toll charge, they may have to tolerate this loss because alternate routes or HOV services are too inconvenient for trips they are making.);
2. Motorists who shift from the tolled road to a competing untolled facility. (The untolled facility is less convenient otherwise these motorists would have used it even in the absence of tolls.);
3. Other users of the competing untolled roadway (since congestion will increase on that road); and
4. Motorists who choose not to make the trip at all because of the toll (or who, with congestion pricing, now drive at a less convenient time of day when the tolls are lower).

One final group may benefit or lose depending on specific circumstances —travelers who switch from driving to HOV or bus services on the tolled road. (Some of those who switch may benefit if the HOV or bus speeds are improved greatly by the tolls, but others may lose if the bus or HOV speed improvements are modest or these modes were fairly inconvenient to begin with).

In this regard, a distinctive feature of congestion pricing is it generates revenue that can be used to offset any such negative effects, by financing transit alternatives where appropriate, or other compensatory actions. Indeed, the reason economists recommend road pricing over regulatory and land use approaches to congestion problems is because it is a policy that has the potential to make everyone better off through prudent use of the revenues generated by the policy. In contrast, regulatory and land use policies produce no revenue, and generally require additional taxation to implement.

The current U.S. practice for recovering costs relating to public expenditures on surface transportation is based on fuel taxes, licensing fees, transit service fares or tariffs, general taxing mechanisms such as sales and property taxes, and the limited application of flat rate tolls applied to selected road facilities (often bridges and tunnels). Most of these mechanisms are either unrelated to the transportation market (the environment in which individuals and firms make consumer and producer decisions), or are based on averaging costs over a wide range of separate cost generating categories. These practices are the particular result of many decades of public financing and provision of transportation infrastructure and services, during which transportation investments were considered to be general public goods. As a result, an ongoing area of analysis has to do with understanding the degree to which various users groups, and tax and fee-paying groups are responsible for the costs of maintaining

and investing in transportation infrastructure and services. Often these policy concerns are characterized as issues of horizontal equity, documenting the degree to which cost responsibility and cost recovery converge.

Numerous cost recovery and cost responsibility studies attempt to detail the degree to which there is cross subsidization of transportation costs between different classes of roadway users. The Federal Highway *Cost Responsibility Study* is a periodic analysis that equates cost responsibility with the recovery of national highway financing costs. The results of this analysis are used to evaluate the adequacy and “fairness” of existing “user fees”, such as national fuel taxes.

Randall Pozdena examined the specific case of California’s road financing structure in 1995 in a paper titled *Where the Rubber Hits the Road*. The summary of this report states the following:

*Overall, the problem with roadway financing in California is not a lack of funds. The problem is that the available funds are not used rationally. The current system of financing leads to a nine fold under-pricing of congested capacity, and a twofold overpricing of uncongested capacity. As things stand, roadway users pay about two cents per vehicle mile traveled on congested roads, instead of the eighteen cents per mile traveled that they should be paying. Users of uncongested roads also pay about two cents per mile traveled while they should only be paying one cent per mile traveled.*

A recent report commissioned by the California Legislature, *Financing Transportation in California: Strategies for Change*, authored by Martin Wachs and colleagues, evaluates the future of California transportation finance. The report documents the limits of existing financial instruments, which have increasingly shifted cost responsibility away from users or beneficiaries, and which are facing greater uncertainty in the face of growing tax aversion. The report recommends returning to the primary use of user fees, and in particular mentions toll and variable toll financing. The report also highlights the importance of pursuing innovative finance structures and arrangements including various forms of debt financing and the use of public-private partnerships.

#### **4.4.1 Different classes of heavy vehicles**

It is generally understood that the existing approach to levying weight fees on heavy vehicles is imprecise with respect to actual cost responsibility. In Oregon this is less true than in other settings but it is still the case that lighter trucks often overpay with respect to the wear and tear costs they impose and the heaviest vehicles typically underpay. An efficient fee system could eliminate this mismatch by including a fee structure that respects the vehicle gross weight, the number axles and the engineering details of the roads that are being used. The question of measuring loaded vehicle weight raises some additional challenges for an efficient fee program as it would likely require on-vehicle scales that are integrated with the fee charging technology.

#### **4.4.2 Rural v. urban v. suburban**

Another set of stakeholders affected by congestion pricing are businesses and residences that are already located in certain urban places. Congestion-based charging influences the value and use of land because it changes the cost of access; some landowners will lose from implementation of congestion-based charges, others will gain. Policy makers also need to know how the land-use effects fit into a region’s objectives for land conservation and development. These issues were considered earlier in this paper under land use effects.

#### **4.4.3 Peak v. off-peak**

Differentiating costs for peak period versus off-peak period road use is a principle feature of an efficient road use fee program. Recovering cost from the users that impose capacity burdening costs on the state of Oregon is a consequence of implementing such a fee program.

#### **4.4.4 Effects on low-income households**

An accounting of the benefits that accrue to users of the transportation system is an important first step in understanding the very large potential merits of network scale road pricing. However, many policy-makers and members of the public will also want to know how those benefits (and the toll burden) get distributed throughout society. Once again turning to the results of the Traffic Choices Study is helpful. The regional modeling of benefits from this study does include, as separate vehicle classes, an accounting of

travel for four individual income classes, as well as other classes of users (trucks, transit, other high-occupancy vehicles, walk and bike). Accounting of income classes is reserved for only home-based work single occupant vehicle trips. So, if trips switch modes from auto to transit or vanpool between the base and the policy or investment scenarios, tracing the user benefit implications becomes slightly less precise. However, retaining this user class disaggregation in the calculation of user benefits provides a reasonable approximation of the distribution of benefits across these classes of users. Exhibit 4.1 contains data about the portion of travel time user benefits that accrue to each class of users. The table also displays the portion of the toll burden borne by each user class.

Low income drive-alone users experience a loss in travel time benefits, and low-middle income users experience only modest gains. Trucks benefit significantly under this tolling scenario. It should be noted that the toll policy did not attempt to optimize the truck toll rates based on the costs (congestion, accident risks, emissions, and road damage) that trucks impose as a consequence of their size and weight. Transit users and high-occupancy vehicle occupants all realize benefits from tolling. All users pay more in tolls than they realize in user benefits, implying that all classes of users would be worse off under tolling if the revenues were simply disposed of instead of reinvested or rebated to taxpayers in the form of reductions in other taxes and fees.

**Exhibit 4.1. Daily User Benefits Without Accounting of Revenue Dispensation**

User Category	Time	Operating Costs	Reliability	Tolls	Total User Benefits
Drive alone home-based work					
<i>Low-income</i>	-\$4,237.55	\$2,879.95	\$77.89	-\$111,459.39	-\$112,739.10
<i>Low middle-income</i>	\$48,664.48	\$12,015.81	-\$4,020.51	-\$391,627.16	-\$334,967.38
<i>High middle-income</i>	\$299,562.32	\$29,797.01	\$15,747.74	-\$1,054,050.81	-\$708,943.73
<i>High-income</i>	\$865,158.48	\$46,848.85	\$68,841.43	-\$1,745,207.90	-\$764,359.14
Drive alone non-work	\$548,909.37	\$121,593.05	\$68,872.94	-\$4,203,786.37	-\$3,464,411.01
Carpool and Vanpool	\$339,375.37	\$65,697.11	\$41,550.26	-\$1,978,324.12	-\$1,531,701.38
Transit	\$156,137.49	\$0.00	\$0.00	\$0.00	\$156,137.49
Light truck	\$1,524,141.85	\$131,363.10	\$260,178.98	-\$2,147,544.47	-\$231,860.55
Medium truck	\$557,553.38	\$65,040.04	\$70,483.24	-\$707,268.03	-\$14,191.37
Heavy truck	\$648,423.62	\$50,158.92	\$71,483.56	-\$861,077.58	-\$91,011.49
<b>All Users</b>	<b>\$4,983,688.80</b>	<b>\$525,393.83</b>	<b>\$593,215.52</b>	<b>-\$13,200,345.82</b>	<b>-\$7,098,047.67</b>

Source: Puget Sound Regional Council, ECONorthwest

**4.4.5 Effects on transit providers**

The primary effect on transit providers from an efficient road use fee is the improved performance for transit vehicles that operate on previously congested roadways. Other effects would include higher patronage and higher cost recovery opportunities that arise when road usage is more costly during peak hours on urban roadways. If transit vehicles are required to pay the road use fees then these would represent a change in vehicle operating cost. However, these higher operating costs would be small in comparison to the gains from improvements in speed and reliability and increased fare revenues.

**4.5 FEDERAL CONSTRAINTS ON TOLLING**

A central question is whether an efficient road use fee is considered a tax or fee or a toll. Current Federal constraints on tolling the interstate system of highways would need to be addressed in advance of any implementation. It is unlikely that such constraints would impede

the implementation of a pilot study as specific provisions for pilot programs have been in place for some time, and Federal support for exploring alternatives to the tax on fuels is ongoing. It is the variable nature of the efficient fee approach that will need to be explored with Federal partners more fully as interest in this topic matures over time.

The handling of revenue generated on federal highways also would involve determining how revenues get remitted to highway authorities and whether the fees would be inclusive of federal taxes.

**4.6 HOW WILL THE ENTIRE ENTERPRISE BE MANAGED**

For the purposes of a demonstration project many of the important questions of how best to design and manage an operational program can be put aside for the time being. A demonstration project can be managed in any manner such that the results of the research effort will be obtained while minimizing

the burden and cost of administration. At an appropriately small scale, questions about what entity in government or the private sector is best positioned to undertake key aspects of operations are secondary to other aspects of experimental design. This will not be the case for full operations. In this light it may be useful to consider the key elements of an operational program in order to begin to think through the process through which a demonstration might eventually transition into full revenue operations.

#### **4.6.1 Policy making**

Policy making for an efficient fee program includes the full complement of operational decisions addressing rate setting, revenue objectives and uses, privacy protections, exemptions or special rules, enforcement and revenue collection methods, and ongoing evaluation and refinements to the program. The key is to have the policymaking body, or bodies, in a direct accountability relationship with system operations. This might imply a tiered approach to itemizing and allocating aspects of policy at various levels of oversight. At the highest level is legislative policy-making and oversight, but many operational policies can be more appropriately placed in the hands of entities that face proper incentives to implement policy that is in the customers' interests. As many aspects of policy will interact with each other in ways that may not be initially obvious, a demonstration project is a useful way to explore and better understand the dynamics between policies and how best to structure a policy development framework for an efficient road use fee program.

#### **4.6.2 Implementation**

There are many approaches to supporting the implementation of a road use fee program. Due to the complex nature of the enterprise it is true that the implementation will involve many state agencies at a minimum, and likely private sector entities as well. A pilot program is less exacting in terms of cost efficiencies due to its temporary nature and smaller scale. As a result the details of an implementation strategy may not be fully mapped out in advance of operating a demonstration project and, in fact, may be informed by experience gained through the pilot program.

#### **4.6.3 Collection, enforcement**

Appropriate governance of the payment processing, collection and enforcement aspects of an operating program will play a very critical role in determining its success. These are the aspects of a program that touch the customers most directly and are also lines of business that government agencies may not have sufficient experience to take on themselves. These are opportunities for partnering with other organizations that specialize in customer service and the unique technical requirements for cost effective payment processing.

#### **4.6.4 Role of local governments**

Local authorities will have a keen interest in an efficient fee program design and implementation. Local authorities are recipients of state road use revenues and also experience considerable traffic and road use effects associated with the current system of fuel taxes. Changes in the fee structures will result

in changes in traffic patterns, by time, location and vehicle type. The patterns of revenues that are remitted to local authorities would also likely change as cost responsibility is more closely adhered to in the fees. For all these reasons local authorities should be included early on in the process of developing a pilot program. Pilot projects afford the opportunity to make advances in implementation without undue burden of process so long as all interested parties understand clearly what the pilot it intended to accomplish and how they will get to participate in understanding and making use of the results of the effort.

#### **4.6.5 Performance measures and evaluation**

Clarity about goals and objectives are also advanced through a program of evaluation that includes discrete measures against which the success of the program can be compared. This is true for both operating programs and for pilot projects. Measures could relate to the operation of the technical systems, the performance of partnering organizations, customer service performance, revenue objectives, research goals, and myriad other aspects of the pilot or the operating program.

### **4.7 HOW COULD REVENUES BE ALLOCATED**

The allocation of revenue from an efficient fee program is possibly the most significant policy question faced by a road authority. As discussed earlier in this paper the benefits of an efficient fee system are largely tied up in the revenues that are generated and allocating these in a useful manner is of the greatest importance.

#### 4.7.1 Overhead, collection, enforcement

The tax on motor fuels has very low administrative costs. No replacement for this tax will be able to achieve similar administrative efficiencies, and any fee system that includes payment processing and communication technologies will have operating costs that are considerably higher. It is not uncommon for electronic toll systems to have toll system operating costs that are 20% of gross revenues. In its infancy, due to inability to take advantage of scale economies, the Oregon Road Use Charge Pilot Program is expected to have operating costs that are higher still. But the expectation is that operating costs in the range of 5% of gross revenue is a reasonable longer-term target. In particular enforcement and payment processing costs can be quite variable across operating programs depending on a wide range of design and policy choices.

#### 4.7.2 Congestion fee revenue associated with specific corridors

The topic of revenue allocation for revenues collected on specific road facilities has been discussed extensively earlier in the paper. This is a policy choice for those involved in designing the fee program. Theory supports the allocation of revenues to those parts of the network, or the owners of those parts of the network, where revenues are generated.

#### 4.7.3 Wear and tear fee revenue associated with facility ownership

With detailed road usage information the appropriate revenues associated with infrastructure wear and tear can be remitted directly to the relevant road authority ex post.

After enough usage and revenue information has been gathered for unique pieces of infrastructure expected revenues could even be allocated ex ante if required to meet maintenance schedules, and then tried up later on. The operative point is that the efficient fee system obviates the need for auxiliary data collection to support the budget development process. In this manner intergovernmental transfers also more closely reflect actual cost responsibility objectives. This is particularly important where heavy vehicles make frequent use of lightly engineered road surfaces.

#### 4.7.4 How would it compare to current revenue allocations?

Current allocations of fuel tax revenues reflect a very general understanding of the share of vehicle traffic local systems endure. A revenue share set aside is then distributed to each local entity based on formula that respects the general size of the entities' driving populations. These methods are clearly an approximate tool for allocating funds to local road authorities. It is feasible to remit to local authorities the exact share of road usage revenues that they are due based on the fee structure rules that reflect cost responsibilities. Fee structures that reflect wear and tear as well as congestion, and even localized pollution costs can be unique to each piece of road infrastructure if needed. It is easy to imagine a nearly impossibly complicated set of fee schedules that would quickly become burdensome to customers but a systematic classification of the important dimensions of costs could easily be devised that would significantly enhance the fairness and utility of the revenue allocation process.

## 5. VARIABLE RATES BUILD ON, AND COMPLEMENT OTHER POLICIES

### 5.1 A NATURAL ENHANCEMENT TO A FUEL TAX REPLACEMENT

The primary differences between variable fees and their flat rate cousins are the need to retain sufficient spatial and temporal details about vehicle use in order to structure a revenue collection program that implements the variable fee. Although early work on mileage fees attempted to design options that would not require the use of vehicle positioning technology, it turns out that spatial details are needed in order to efficiently and accurately administer a simple flat rate fee program.

An examination of the operating requirements for the Oregon Road Usage Charge Pilot Program reinforces this basic understanding. Both the System Requirements Specifications (2012) and the Open System Architecture Model (2012) clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics.

The significant advantage of this compatibility between the variable fees of an efficient fee system and the systems that are to be used for flat rate mileage fees are fairly obvious. A single back office and technical platform offers considerable cost savings with respect to both eventual revenue operations and for the implementation of pilot studies and trials. There will be significant additional benefits associated

with building on the planned technical and administrative infrastructure that will be employed to implement a flat rate mileage fee. These added benefits relate to legal, policy, administrative processes. It is also true that the basic principles involved have a common origin, including:

- Cost recovery
- Fairness
- Adequately finance the system
- Guide investment decisions

It happens that a variable rate structure is superior to a flat rate structure in terms of achieving each of these objectives.

#### 5.1.1 Build on policy and technical infrastructure for mileage fee

A variable fee on vehicle use builds naturally on the underlying logic and technology of a flat rate mileage fee. The efficient fee approach has several advantages over the traditional approach to highway cost allocation:

- It is not affected by year-to-year variations in the mix of project types undertaken by the agencies
- It is not affected by budget constraints that result in under spending by agencies
- It is not affected by the inherently “lumpy” nature of investment in transportation infrastructure

If an efficient fee approach to highway cost allocation were used, the benefits would likely include the following:

- Each vehicle would pay exactly the costs it imposes, which can be much fairer than equity

between weight classes, and which aligns each vehicle operator’s behavior with what is best for society. A vehicle would travel when the benefits of the trip are greater than the cost to the traveler and to the rest of society.

- Vehicles would make different numbers of trips and some trips would be at different times or on different routes than under the traditional highway user fees, resulting in a more efficient use of existing infrastructure.
- Where carpooling, transit, biking, or walking are viable alternatives to single-occupant auto travel on congested roads, their share of trips would increase, resulting in a more efficient use of existing infrastructure.
- The collected revenues would, by definition, be just sufficient over time to provide the optimal amount of new capacity and the optimal levels of preservation and maintenance for all facilities.
- In the long run, efficient pricing would lead to more efficient land uses and transportation infrastructure investments through voluntary rearrangements that are beneficial to those making the changes.

To achieve these benefits, efficient fees must actually be levied and their levels must be communicated to travelers at the time travelers make relevant decisions.

#### 5.1.2 Wear and tear fees could vary with weight, axles, studded tires, and road type

Wear-and-tear fees recover the future maintenance, preservation, and capital replacement costs a vehicle imposes by wearing out the roadway it drives on. The

sum of all wear-and-tear fees represents the optimal level of expenditure on maintenance, preservation, and capital replacement and does not depend on actual expenditures in any particular biennium or the cost-effectiveness of actual maintenance and preservation programs.

Wear-and-tear fee components cover roads and bridges and vary with the weight and configuration of the vehicle, the presence of studded tires, and the proportion of degradation on the particular facility that is due to use (as opposed to decay that would occur over time even in the absence of use). The higher the proportion that is due to use, the higher the cost per user-mile.

Oregon’s existing weight-mile tax is an example of a wear-and-tear fee that is much closer to efficient than the revenue instruments used for heavy trucks in other states.

#### 5.1.3 Congestion fee could vary with time and place of travel and vehicle PCEs

A congestion fee recovers the future costs associated with investing in additional capacity or otherwise relieving congestion. It is based on the costs a vehicle imposes on other vehicles by taking up space on a particular facility at a particular time and is a function of the value of other travelers’ time and the amount by which the vehicle slows traffic.

Congestion-related costs can vary greatly over the road network and the course of a day. And to promote efficient use of the facility, congestion fees must reflect those costs by varying with actual traffic volumes and roadway capacities. In implementation, the prices are could be recalculated continuously and can

change every few minutes if necessary to reflect changing traffic conditions, or can be a fixed schedule of time varying charges.

Efficient congestion fees reflect a facility's capacity and potential for congestion, the current traffic volume, and the characteristics of the vehicle paying the fee. Longer vehicles and vehicles that require additional space because they accelerate and decelerate more slowly each contribute more to congestion than does a single passenger car. Congestion fees are calculated per passenger car equivalent (PCE) mile. While efficient congestion fees can produce significant revenue (estimated at over \$200 million per year in Oregon), they will be at or near zero at most times on most roads.

#### **5.1.4 Possible additional per-mile rate for overhead**

An administrative fee recovers the cost of highway agency activities not directly covered by the congestion or wear-and-tear fees, such as planning, administration, finance, information services, and collection costs for user fees. The Oregon Highway Cost Allocation Study provides a long history of analysis on cost responsibility in the state of Oregon. This analysis can become the framework for identifying an administrative fee component of a variable rate road-charging program.

#### **5.1.5 Other potential fee components**

An emissions fee component could recover the costs imposed on others by the emissions produced by the vehicle. In the case of electric vehicles, it may include the emissions produced in generating the electricity used to charge

the vehicle. Charging the emissions fee leads to optimal emissions levels regardless of how the revenue is spent. Emissions fee revenues could then be spent on offsetting administrative costs, reducing the administrative fee needed. Components representing fees for other externalities imposed by vehicles could be included as well. The concept for other fees is the same as with emissions. To be included, the externality must be quantifiable, there must be a defined relationship between the quantity of travel and the quantity of the externality produced, and there must be a defined cost per unit of externality, which may be negative in the case of an external benefit.

### **5.2 EFFICIENT PRICING WOULD COMPLEMENT OTHER STATE POLICIES**

Road management and surface transportation policy do not exist in isolation from other aspects of urban systems management. It is therefore important to consider an efficient road usage fee program in light of a range of other policy interests and objectives. Some of these are discussed briefly below, but all of these can be evaluated further as a result of a pilot project implementation.

#### **5.2.1 Land use goals and TPR**

Generally, the effects on land use depend on the comprehensiveness of coverage of the congestion pricing system. If the coverage of the congestion pricing system is reasonably complete (i.e. comprehensive, mileage-based regional pricing is employed, without major traffic diversion to unpriced facilities), congestion pricing likely will tend to reinforce existing

employment centers. (As outlined by Deakin, 1993, the use of the pricing revenues will also impact the potential for affecting urban form.)

This follows despite the fact congestion pricing will raise the out-of-pocket cost of the home-to-work trip. The relevant cost measure to consider for land use analysis purposes, is the full cost of travel (including time), not just the cash cost. Although congestion pricing raises the cash cost of travel in the peak period, it should lower time costs and travel costs overall, especially if HOV services respond appropriately and the congestion pricing revenues are efficiently spent. (Indeed, to the extent that congestion pricing policy fails to lower total travel costs, it has not been properly implemented. After all, the logic of congestion pricing is to improve economic efficiency, which implies, by definition, the use of fewer economic resources, not more.)

Congestion pricing thus should improve formerly-congested access to existing locations, which should improve these locations' competitive viability in the region. In turn, to the extent the rising cost of congestion to and in the CBD is a major contributor to the trend of employers moving to suburban locations, it is theoretically possible that congestion pricing may help existing centers.

Thus assuming reasonably comprehensive, regional implementation of congestion pricing, the result could be less development sprawl. This follows from the fact that such a pricing system can introduce a bias in favor of:

- Short over long trips, since vehicles pay by the mile;

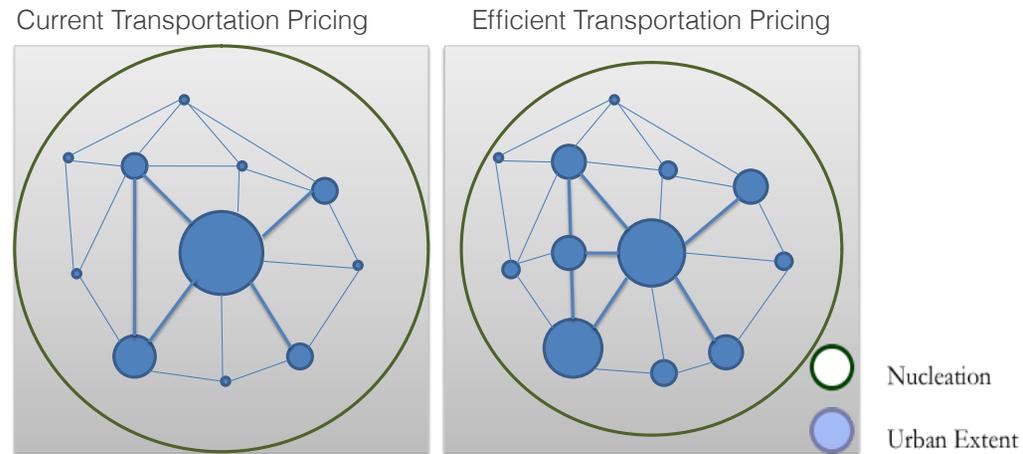
- Trips in corridors served well by transit alternatives (or in which carpooling or vanpooling is convenient), since this represents an important way for travelers to avoid the congestion tolls.

Computer simulations of comprehensive congestion pricing policy have demonstrated that a comprehensively-applied congestion pricing system can favor the CBD and major centers, and discourages diffused suburbanization of economic activity. However, such simulations are necessarily very abstract, and may or may not faithfully capture the real-world response to congestion pricing.

We can say with certainty that the decentralization that has occurred in American cities has occurred in the absence of congestion pricing. Whether implementation of congestion pricing will reverse those trends is much less clear. Comprehensive congestion pricing will have centralizing effects on land-use patterns, since the attractiveness of the downtown location is maintained or enhanced by the policy. Whether this is enough to reverse 50 years of decentralization is, frankly, not known.

If congestion pricing coverage is incomplete, with only a few facilities priced properly, its effects are likely to be even more difficult to predict. At best, the effects on land use would be a spotty rendition of the effects described above; at the worst, depending on the policy practiced on the unpriced portion of the roadway network, congestion pricing could exaggerate the tendencies for business activity to dissipate in the region.

### Exhibit 5.1. Road Pricing and Polycentric Urban Form



The worst case would arise if congestion pricing is implemented only on a selected facility and is implemented in an erroneous fashion. In particular, if the prices are set too high, and/or the revenues collected from the congestion prices are spent in a way that does not improve travel conditions on the affected facilities, congestion pricing would have mostly bad effects on development patterns. In this case, many of the travelers will perceive (properly) that the policy has, in fact, increased their full cost of travel, and may locate their residences or businesses to avoid this impact.

One possibility that appropriately concerns downtown interests, for example, is that congestion pricing is applied selectively to congested, CBD-oriented roads, and then the revenue is dissipated. Mismanaged congestion pricing in this case probably would encourage:

- Diversion of development to the unpriced portions of the region;

- Suburbs-oriented trip-making (if CBD trips are priced and suburban trips are not).

From this discussion it is obvious that it may not be possible to forecast exactly the winners and losers from congestion pricing because the outcome depends on:

- How well, and how completely, congestion pricing is implemented;
- How efficiently the revenues collected via congestion pricing are utilized.

All economists can urge in this regard is that the congestion pricing revenues be used, to the extent possible, in the corridor in which they were generated to redress the income distributional effects of congestion pricing. Most importantly, if the revenues are not used efficiently, congestion pricing may not generate overall net benefits and it would be unfair to ask the public to support it.

### 5.2.2 Oregon Sustainable Transportation Initiative (OSTI)

The Oregon Sustainable Transportation Initiative (OSTI) is an integrated statewide effort to reduce greenhouse gas (GHG) emissions from transportation while also supporting healthy, livable communities and economic opportunity. The effort is the result of several bills passed by the Oregon Legislature, and it is designed to help the state meet its 2050 goal of reducing GHG emissions by 75 percent below 1990 levels.

An efficient road use fee is uniquely suited to support the major goals of the OSTI. The reason is that an efficient fee for road use will have broad effects on how urban systems interact with each other. As a starting point an efficient fee addresses reoccurring congestion on major roadways. Less congestion results in travel time savings that get capitalized in the broader economy. The production possibilities for the Oregon economy are thus improved. The improved performance of the urban road network also reduces GHG emissions as moderate speeds are maintained even during peak travel periods. In addition, as discussed above, an efficient transportation fee will influence the spatial pattern of the economy and naturally support more compact use of desirable urban land without resorting to regulatory approaches that can be overly prescriptive or crudely applied.

### 5.2.3 Greenhouse gas reduction policies

To the extent congestion pricing reduces air and/or noise pollution, as an ancillary effect to VMT reduction, there may be general environmental benefits. An ODOT

commissioned paper on road pricing's role in reducing greenhouse gases addresses many relevant issues.

The issue is not as straightforward as it seems, however. One of the effects of congestion pricing, for example, is to cause vehicles remaining on the roadways to travel at higher speeds. Typically, the rate of emissions, per mile, increases at higher speeds (as do motor and tire noise as well). Hence, whether there are pollution benefits, on balance, will depend upon the partially offsetting effects of higher speeds and lower traffic levels.

In addition, congestion pricing does not necessarily reduce travel by the most polluting vehicles or reduce the number of cold starts. It is possible, for example, that when faced with higher out-of-pocket costs from congestion prices, drivers may try to economize by retiring old vehicles more slowly. And if most of the reduction in congestion come from spreading of the peak (rather than reduction in trips), cold starts may not be reduced significantly either.

Detailed studies of congestion pricing in California and Washington suggest that congestion pricing, on balance, does have beneficial air pollution effects. However, because of the uncertainties involved, policies focused directly on vehicle emissions generally are preferred to relying on the ancillary effects of congestion pricing. An ODOT paper from 2009: *Tolling White Paper #1: Potential Effects of Tolling and Pricing Strategies on Greenhouse Gas Emissions* examines greenhouse gas emissions opportunities from road pricing for Oregon. Conclusions from this paper include

the observation that road pricing's influence on emissions is largely a function of its ability to improve roadway operating speeds and that overall effect on emissions will be dependent on the scale and extent of a road pricing application.

### 5.2.4 Numerous other programs and incentives

There are numerous additional objectives, programs and existing incentive systems that are important to the state of Oregon. These include, but are not limited to the following:

- Freight Movement
- Efficient Infrastructure Development
- Infrastructure Condition and Reliability
- Efficient Land Use
- Travel Demand Management
- Active Transportation
- Energy Demand Management
- MPO-level Transportation and Land-use Planning

An efficient road use fee system can advance objectives in each of these areas.

## 6. HOW TO MOVE FORWARD

### 6.1 DEMONSTRATION DESIGN

Demonstration project design should begin with clear objectives, then outline what is required to meet those objectives. The objectives of an efficient vehicle fee program include the following:

- Charge vehicles the costs they impose on the transportation system; including the wear and tear cost on infrastructure, the costs of building new capacity as existing capacity

is burdened, and cover other external costs such as pollution and noise.

- Improve fairness by recovering these costs from the specific vehicles that impose those costs
- Sustainably fund transportation maintenance and investment programs over the long-run through the revenues generated from the efficient fees.

But the objectives of a pilot study can differ from the program objectives. For example one pilot project objective might be to fully solve how best to structure payment systems, enforcement, or protect privacy while designing a program that is striving to reach the broader policy objectives listed above. Pilot, or demonstration, project objectives are guided by an overall strategy for determining how to advance the broader program of efficient fees.

Demonstrations of new programs or policies tend to fall into one of two categories: general demonstrations and technical demonstrations. General demonstrations focus on proof of concept, building awareness, and identifying policies that need further investigation. Technical demonstrations involve a more formal testing of some specific functional aspect of a new program. The two categories are not entirely exclusive, of course, allowing a combination of objectives to be met with any given demonstration project design. In the case of an efficient fee demonstration in Oregon what is required is to build awareness about the subject, identify policies of importance as these ideas gain momentum, and to prove out the basic structure of an efficient fee program

to a broad audience. Much has been done elsewhere (e.g. Seattle, Atlanta and Oregon in the U.S. and Germany, UK and the Netherlands in Europe) to design and test specific technical implementation aspects of mileage fees, or what are often referred to as Road User Charges. And the technology required and the organizational management approaches and practices in this arena will continue to evolve quite rapidly. In summary, a demonstration project in Oregon will likely be a combination of a general and a technical demonstration.

If the intent is to fully design and field-test a comprehensive approach to efficient fee implementation then there is a very long list of issues that need resolution. And as such the decision-making agenda to support that process would be extensive. One approach to moving forward involves a recognizing that the work to be done is too detailed and too broad to undertake everything in one pilot. The only example where there was an attempt to resolve all policy and implementation questions in one field trial was the Dutch road pricing program. The Dutch spent tens of millions of dollars over many years, and included significant industry consultation in a design a pilot that would then roll right into implementation if it proved successful. This was a high-risk approach with potential high reward, but in the end changing politics derailed the pilot.

If on the other hand the intent of a pilot is to more fully understand a single aspect of policy (take privacy for example) then the decision-making factors are more limited in scope, but a lot more detailed and specific. It is always beneficial to first know what it is that folks are

hoping to discover through the demonstration in advance of adding this additional detail. In truth, a demonstration project can be used to do any number of things, including:

- Explore one single dimension of policy
- Design a single aspect of an operational program
- Test general feasibility of a broader policy program
- Field test technology

The basic order of steps involved in getting through the numerous decisions involved in designing and implementing a demonstration project might include the following.

1. Determine the general objectives of the demonstration (technical trial, broad policy design, detailed programmatic design, etc.)
2. With the above determined, sketch out a decision agenda that ensures the demonstration will produce the desired results.
3. Fit the results of the demonstration into a larger policy agenda for advancing the overall practice around efficient fees.
4. Number 3 above may necessitate further demonstrations of technology, or pilots to design a specific aspect of the program.
5. Communicate the importance of the broader policy agenda and the specific benefits of the well-designed demonstration project that will help everyone involved to refine policy and advance the practice in a manner that will be acceptable to the general public.

The myriad of road charging trials in the U.S., but also substantially in Europe, has resulted

in clarity on whether such systems would work technically. It has been demonstrated that even the costs of implementation would be exceeded by the efficiency gains and revenue opportunities an efficient fee system offers. The primary potential objections relate to how exactly such a fee system would affect peoples' lives. While it is fairly easy to predict the overall magnitude of fees, revenues and benefits, it is considerably more difficult to be specific about the distribution of these effects across members of the general public without an opportunity to observe behavior that is part of a carefully designed demonstration project. This type of effort has only been undertaken in the Puget Sound region, nearly a decade ago and involving a limited sample of participants.

In addition, the question of how Oregonians will respond to an efficient fee that involves vehicle-positioning technology, and how a system can be designed to safeguard privacy, needs further detailed exploration.

Demonstrations are an expensive undertaking and should be designed carefully. What follows is a list of potential priorities for efficient fee demonstrations in the US market:

1. Pilot systems that will truly address privacy concerns. These concerns necessitate both technical and administrative systems that will need to be designed and tested against "hostile" participants to see if there are weaknesses and if people can break the security.
2. Demonstrate the merits of integrating fee and investments policy. It needs to be demonstrated that the benefits of the efficient

fee system will materialize for consumers. Most people think these efforts are about grabbing revenues and they will need to be shown how investment policy can be improved in a manner that meets their needs.

3. Design a pilot that will fully explore the incidence of fee payment. Such an effort would understand efficient fees with respect to alternatives to the efficient fee system and with respect to user income. The effort would strive to fully explore questions around fairness in a manner that sheds real light on this issue.

4. Technical systems that support an efficient fee are available. There is no need for a general technical trial, only trials of very specific technical solutions to specific problems such as payment processing and enforcement of very specific programs.

If there is clarity on the general objectives of the "next" trial then these pilot project objectives can then get translated into demonstration project operating requirements. Beyond requirements, it is necessary to put additional shape on the skeleton of the design in order to allow for a budget estimate to be developed. The design that follows has benefited from relying on experience in actual demonstration project implementations and as such is rooted in practical knowledge that is key to understanding budget and schedule risks.

#### **6.1.1 Summary of Proposed Efficient Fee Demonstration**

A demonstration of an efficient road use fee in Oregon might look something like what is summarized below. The process of developing this description is one that begins with a set

of demonstration project objectives and the identification of functional requirements that address those objectives. The description of the demonstration then follows from the functional requirements. Demonstration project objectives and requirements are described in more detail later in this section of the paper.

To demonstrate the operation of an efficient road use fee it is envisioned that a groups of participants will be recruited from the population of Oregon residents. These participants will have their vehicle equipped with mileage fee metering devices for the duration of the demonstration. Participants will drive normally during a baseline data collection period. This baseline period will establish the driving patterns for each household. During the experimental period of the demonstration project the participants will be exposed to the efficient fee. All the major operations aspects of an actual efficient road use fee will be implemented and tested including, the back office functions, payment processing, and customer services. Many of these functions are already in operation to support the Oregon Road Usage Charge program. Participating households will not be asked to pay the fee out of their own pockets, but they must also face an actual incentive to align their driving behavior with the hypothetical mileage fee charges. To accomplish this objective the project will provide participating households with a travel budget account out of which fees will be deducted. The incentive is realized because participating households are allowed to keep whatever balance remains in their account at the end of the experimental period.

Such a demonstration allows for a rich evaluation of driver behavior, support the estimation of revenue yields from alternate mileage fee policies, tests the operations of the set of systems design to support implementation, permits the examination of how local option taxes could get included in an efficient fee, and tests a range of important topics (e.g. privacy, equity) that relate to policy. A successful implementation of a demonstration project such as this adds considerably to the inventory of knowledge about road use fee viability and design and should be of interest to a broad set of stakeholders and levels of governmental management.

### 6.1.2 Demonstration Project Objectives

Demonstrations of new programs or policies tend to fall into one of two categories: general demonstrations and *technical* demonstrations. General demonstrations focus on proof of concept, building awareness, and identifying policies that need further investigation. Technical demonstrations involve a more formal testing of some specific functional aspect of a new program. This effort has aspects of each of these categories with a combination of objectives to be met through demonstration project design. There have already been a number of demonstration projects implemented within the U.S. (with Oregon leading the way) and so the basic feasibility of doing so in Oregon is clearly established. As a result a demonstration project will be part of a broader body of ongoing research and exploration. An NCHRP report developed by the RAND Corporation outlines some guidelines for the design of additional mileage fee, or road use charging demonstrations. In particular future demonstration projects might beneficially focus on one or more of the following topics:

- Explore a range of technical issues that surround implementation
- Understand driver behavior in response to new fee structures
- Determine the process through which mileage fees are phased in as other highway finance approaches (fuel taxes, tolls) evolve or remain in force
- Identify institutional issues that will present themselves during the design and implementation of a mileage fee system
- Establish pricing and rate setting policies beyond a simple fuel tax replacement

- Explore factors that influence user acceptance of mileage fees
- Design solutions to privacy and evasion problem associated with an implementation of mileage fees

In cases where the mileage fees vary by time and location, travel behavior will be more significantly influenced. As a result a comprehensive demonstration would not be limited to only technical issues but would involve human participants and an attempt to understand the range of potential behavioral responses to the fees. Demonstration projects that recruited volunteer participants and measured behavioral responses have been implemented recently in the U.S., and the design requirements and costs are well understood. A fee structure that is relevant to Oregon might include fees that are higher in urban downtown settings during peak periods of travel. There could be a number of variations on these themes.

An efficient fee affords the opportunity to recover the primary costs of provisioning and operating transportation infrastructure from transportation system users. When the mileage fee is a variable fee, as opposed to a flat fee, then there is also an opportunity to improve the fairness of the cost burden, begin to minimize the large social costs of highway congestion, and even to address other costs of transportation such as vehicle emissions.

### 6.1.3 Demonstration Project Design Features

Design features for an efficient road use charge might start with the following:

1. A variable rate mileage fee with some opportunity for fee structure modification to accommodate localized variation in the rates to address vehicle type or congestion.
2. A larger-scale demonstration project (500+ participants) allowing for behavioral analysis and generalization of findings to a larger population.
3. A demonstration that includes the implementation and testing of the various aspects of payment processing (account development, data communication, central office support services, financial transactions, etc.).
4. A demonstration project that includes an assessment of the opportunities for efficiency gains in terms of traffic congestion.

5. A demonstration project led by the State with strong coordination and involvement from the local authorities.

Based on the broad set of important objectives it will be important that a demonstration project in Oregon be designed to be a comprehensive pilot project. One important point of discussion involved the scale of the demonstration project implementation. Features of a comprehensive demonstration are summarized in [Exhibit 6.1](#).

The proposed demonstration project design is intended to represent a project that could be implemented in Oregon in order to meet a set of carefully considered demonstration objectives. While the design has been thoughtfully developed it is intended only as a guide to implementation. As the preparations for implementing a demonstration project progress it is certain that project objectives and the resulting technical requirements will be modified. Consistent with this understanding, the design is organized around functionality rather than specifications. The core functionality is what needs to be supported by technical systems and experimental and analytical methods.

#### 6.1.4 Participatory Demonstration and Experimental Design

The dominant feature of the proposed demonstration project is that it will make use of volunteer participants in order to test a full range of important aspects of an actual efficient road use fee implementation. This is in contrast to some kinds of technical demonstration that are intended to prove out new technical system, often involving test facilities and technicians and test professionals.

Other participatory demonstrations involving instrumented vehicles have been implemented elsewhere and as a result this effort will not start from scratch or attempt to re-implement efforts already proven successful.

Using actual participants allows for a deep understanding of behaviors, choices, and the consequences for consumer benefits. All important aspects of policy, including revenue incidence, implications for congestion and infrastructure improvements, fairness, and approaches to privacy protection require actual participants to be the core organizing principle of the demonstration design.

Measuring the effects of the program specifically introduce the need for careful experimental design. The primary challenge is preserving a

### Exhibit 6.1 Limited and Comprehensive Demonstration Design Feature Options

Demonstration Design Feature	Limited Demo	Comprehensive Demo
<b>Fee rate structure</b>		
Flat rate fee	●	●
Variable fee by time of day, location, vehicle		●
Local option taxes		○
<b>Demonstration subjects</b>		
Random recruitment		●
Self-selected participants	●	
Targeted group of participants	○	○
<b>Scale of demonstration</b>		
Less than 500 participants	●	
500+ participants		●
<b>Geographic extent</b>		
Entire metropolitan region		●
Subset of metropolitan region	●	○
<b>Demonstration of operational functions</b>		
Payment processing systems	○	○
Vehicle metering technology		●
Enforcement systems design		○
Private operator/vendor involvement		●
<b>Demonstration policy emphasis areas</b>		
Privacy protections	○	○
Gains and losses to subpopulations		○
Out of state vehicle program design	○	●
Transitional strategies		○
User acceptability and education program	○	●
Fee rate setting and disposition of revenues		○
<b>Management of the demonstration</b>		
MetroPlan and State partnership	●	●
Federal support		○
Mileage-Based User Fee Alliance		○

Source: ECONorthwest

control against which behavior, modified by experimental treatment, can be compared. The proposed demonstration is likely to involve a quasi-experimental design.

### 6.1.5 Variable Rate Fee Structure

The efficient fee demonstration should support the testing of a variable rate fee applied to miles driven by participating vehicles. In this manner the project will better understand how differences in fee design influences in various outcomes of interest including user behavior, user and economic benefits, revenue opportunities and a wide range of other factors. Applying variable fees for road use provide an opportunity to make road use fees more closely reflect the costs that vehicle use imposes (described more below) in the form of road wear and tear, capacity burdening that engenders capacity improvements, and a range of other factors that may be time and location dependent. The fee structure could include one or all of the following.

#### *Wear and Tear Fee*

Wear-and-tear fees recover the future maintenance, preservation, and capital replacement costs a vehicle imposes by wearing out the roadway it drives on. The sum of all wear-and-tear fees represents the optimal level of expenditure on maintenance, preservation, and capital replacement and does not depend on actual expenditures in any particular biennium or the cost-effectiveness of actual maintenance and preservation programs.

Wear-and-tear fee components cover roads and bridges and vary with the weight and configuration of the vehicle, the presence of studded tires, and the proportion of degradation on the particular facility that is due to use (as opposed to decay that would occur over time even in the absence of use). The higher the proportion that is due to use, the higher the cost per user-mile.

Oregon's existing weight-mile tax is an example of a wear-and-tear fee that is much closer to efficient than the revenue instruments used for heavy trucks in other states. Incorporating such a fee structure into an efficient fee program that applies to all vehicles in Oregon is a feasible undertaking.

#### *Congestion Fee*

A congestion fee recovers the future costs associated with investing in additional capacity or otherwise relieving congestion. It is based on the costs a vehicle imposes on other vehicles by taking up space on a particular facility at a particular time and is a function of the value of other travelers' time and the amount by which the vehicle slows traffic.

Congestion-related costs can vary greatly over the road network and the course of a day. and to promote efficient use of the facility, congestion fees must reflect those costs by varying with actual traffic volumes and roadway capacities. In implementation, the prices are recalculated continuously and can change every few minutes if necessary to reflect changing traffic conditions.

Efficient congestion fees reflect a facility's capacity and potential for congestion, the current traffic volume, and the characteristics of the vehicle paying the fee. Longer vehicles and vehicles that require additional space because they accelerate and decelerate more slowly each contribute more to congestion than does a single passenger car. Congestion fees are calculated per passenger car equivalent (PCE) mile.

#### *Administrative and Other Fees*

An administrative fee recovers the cost of highway agency activities not directly covered by the congestion or wear-and-tear fees, such as planning, administration, finance, information services, and collection costs for user fees. The Oregon Highway Cost Allocation Study provides a long history of analysis on cost responsibility in the state of Oregon. This analysis can become the framework for identifying an administrative fee component of a variable rate road-charging program.

An emissions fee component could recover the costs imposed on others by the emissions produced by the vehicle. In the case of electric vehicles, it may include the emissions produced in generating the electricity used to charge the vehicle. Charging the emissions fee leads to optimal emissions levels regardless of how the revenue is spent. Emissions fee revenues could then be spent on offsetting administrative costs, reducing the administrative fee needed.

## 6.2 DATA REQUIREMENTS

Ideally an efficient fee pilot project would be designed in a manner that takes advantage of large quantities of high quality information about attributes of the driving population as well as a detailed understanding of their behavior and price sensitivities. Comprehensive data of this kind is never available and is expensive to generate. Luckily one of the key merits of a pilot project is that it is a trial and getting prices exactly "right" up front is not critical. Also, the nature of variable fee structures is that they are

designed to respond to changing conditions and demands. And the data that is required that allows for fees to respond to these changing conditions are generated from the fee program itself. It is still true that a starting point for the design of an efficient fee will benefit from some basic data on traffic conditions and costs. And travel models can be a useful means of discovering the underlying parameters for an efficient fee structure.

**6.2.1 Detailed traffic data**

Detailed traffic data, including counts and speeds by vehicle class by facility by time of day are useful in developing a variable rate fee structure. An example of this kind of data that is collected from loop counters in the freeway network from the Seattle area is displayed below. Exhibit 6.2 illustrate the 24 hour diurnal traffic patterns for a selected freeway location within the Seattle area freeway network. These patterns were used to help identify appropriate times to vary toll rates according to levels of demand for the Traffic Choices study.

**6.2.2 Detailed cost data by facility**

Traffic data is useful in estimating the congestion fee portion of an efficient fee but information about the costs of maintenance and preservation of road assets is useful in estimating the wear and tear portion of the fee. The long history of the Oregon Highway Cost Allocation Study provides extensive data on the marginal and average maintenance and preservation costs by facility type.

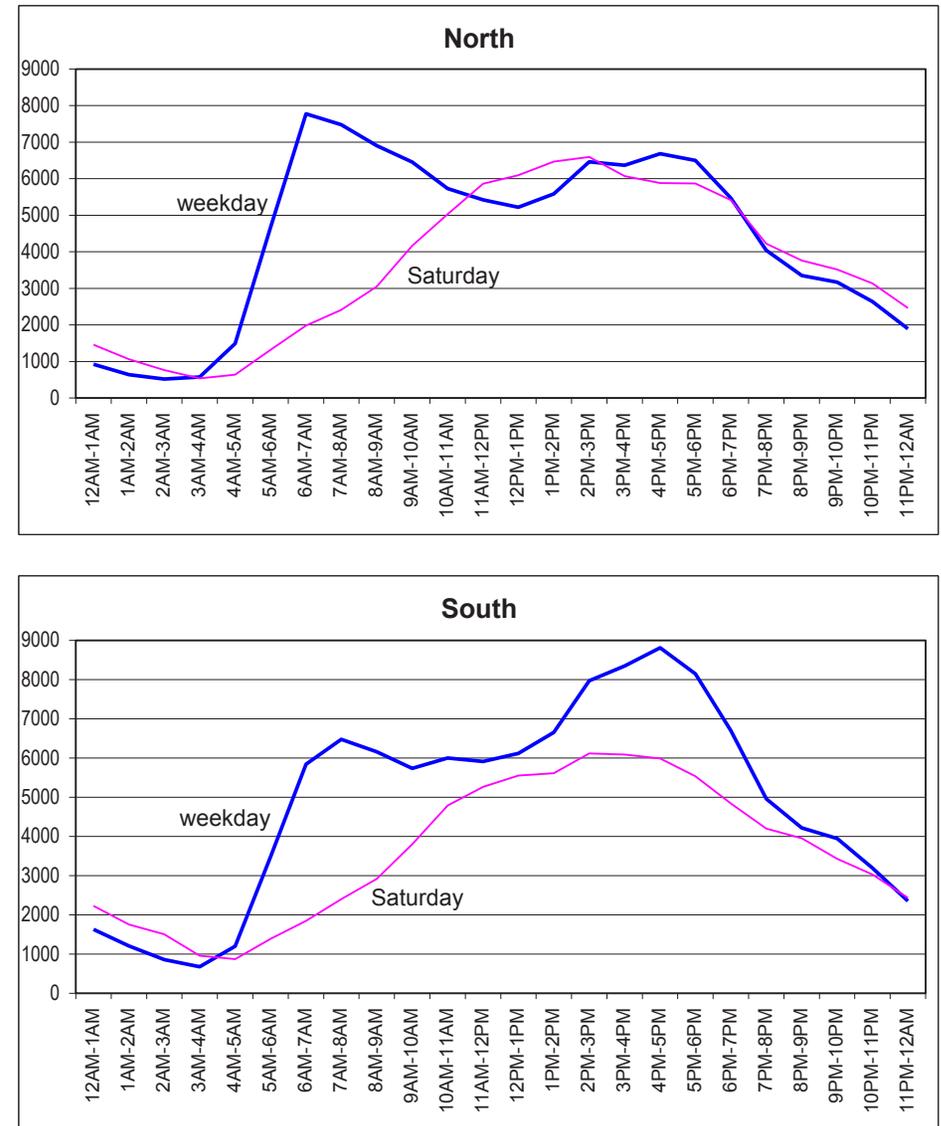
**6.2.3 Travel demand models for areas with significant congestion**

A travel demand model is a good starting point for understanding the appropriate fee structure that might get applied to any given road network. ODOT's *Tolling White Paper 3: Travel Demand Model Sufficiency* discusses Oregon specific topics in travel demand modeling of tolling. Taking advantage of the approaches to highway assignments under congested conditions that are inherent to these models is a reasonably straightforward exercise that yields first approximations of an efficient fee structure. Such an exercise was done in support for the Traffic Choices Study in Seattle.

The PSRC travel demand model was used to study travel patterns on the toll network. The main purpose of the study was to establish the distribution of toll costs during a typical travel day, paying particular attention to how these costs varied with the facilities used, time-of-day and direction of

**Exhibit 6.2. Diurnal Traffic Flow Example**

**I-5 @ S Holden St / Boeing Field**  
(south of downtown Seattle)



Source: Puget Sound Regional Council, ECONorthwest

travel. Link toll costs are assumed to be a function of the link volume-to-capacity ratio, with the specific functional form varying by facility type (see Technical Memorandum PB4). The analysis is based on network traffic volumes obtained from a 1998 base scenario, estimated using the toll-free (as opposed to the toll-augmented) volume-delay functions, and on travel demand matrices segmented by time of day (AM Peak, PM Peak and Off-Peak).

The model data were examined from two different angles: first to establish average and range of the trip-based toll costs that would be incurred given existing travel patterns, and second to establish link-based toll costs as a function of facility characteristics. The latter measure helps to establish toll rates by facility type (and other network-based characteristics), while the former measure helps understand the cost to travelers implied by the link-based toll rates.

The economic principle underlying the tolling scheme developed recognizes that the social marginal cost of travel exceeds the private marginal cost recognized by the vehicle user (described previously in this paper). The PSRC regional model was used to determine the VMT-weighted average toll rates as well as toll rate variation for all freeway/expressway facilities and all arterials. Not all roads are sufficiently utilized to warrant a toll at all times of the day and/or directions of travel. However, in the interest of keeping the tariff structure reasonably simple to grasp and remember, it was necessary to develop a toll schedule that was logically tied to these average toll rates (based on the weighted average external costs imposed per vehicle). The use of the weighted

average external cost toll rates recognizes that some roads will be overpriced, and others underpriced; in fact, some variability of this type is actually desired for the statistical analysis and assessing the confidence intervals around resulting elasticity estimates.

The average arterial road toll rate per mile was almost exactly one-half of the average freeway toll rate during both the three hour AM and PM peak periods. Combined, the two peak periods comprise 25% of the day, but account for 43% of daily VMT. For the model's off-peak period — the remaining 18 hours of the day with highly variable traffic conditions ranging from peak shoulder hours to the middle of the night — the average arterial toll rate was 57% of the same freeway toll rate.

The consistency of the average ratio between the economically efficient toll rates for freeways and arterials led to one of the simplifying assumptions for the study — that the arterial toll rate per mile would always be one-half of the corresponding freeway rate at any given time of day.

The composite measures served as base values for a series of tariff structure and toll schedule options that were considered. Each option examined variation from the average base toll rates in a number of dimensions, including travel direction, proximity to the urban core areas, and additional time of day differentiation. The pros and cons of these options were then considered by the study team, weighing statistical analysis advantages of complexity against participant comprehension.

The final tariff structure shown in represents a compromise that was intended to provide ample

opportunities for statistical analysis and price elasticity estimation, while at the same time retaining an aspect of simplicity that will facilitate rational behavior modification by participants.

### **6.3 TECHNOLOGY THAT SUPPORT AN EFFICIENT FEE PROGRAM**

Standard practice in electronic tolling involves the use of relatively simple in-vehicle radio tags, or transponders (e.g., FasTrak or E-Z Pass). The radio tags contain a unique electronic signature that is communicated to roadside equipment as the equipped vehicle drives by. Current systems use various short-range communication technologies and protocols and are typically implemented with proprietary hardware and software elements. Roadside equipment includes the toll tag readers and any equipment necessary for vehicle classification and enforcement, as well as equipment to transfer all necessary transaction information to a central toll operations center. This electronic toll collection approach has been used successfully since it was first introduced in the late 1980s.

Similar technology has been used in the Singapore-area pricing program since 1998. The London Congestion Charging Zone also relies upon roadside equipment for vehicle identification and account processing, although in London video cameras capture the license plates of each vehicle entering the charging zone. Cameras are positioned at all points of access to the zone and also at key locations within the zone.

These approaches require that dedicated roadside tolling equipment be deployed over the full extent of the tolled network and, as a

consequence, also require new infrastructure any time the tolled network is expanded or altered. The approach to network tolling that was investigated as part of the Traffic Choices Study in the Seattle area did not rely on roadside equipment, although enforcement would depend upon strategically located video license plate reader equipment. The in-vehicle tolling devices locate the vehicle on the road network and communicate directly with the central tolling operations system, resulting in significantly less civil infrastructure, and enabling flexible extensions or alterations of the tolling network.

To date, there are few true network charging programs in operation. Heavy vehicles are tolled on major roads in a few European countries, and the Netherlands is making progress toward a national kilometer charging program to be implemented by 2016. With few operational systems, and none that rely exclusively on GPS-tolling technology, there have been lingering questions about the complexity and cost of such an approach.

The in-vehicle electronic toll collection system elements implemented for the Traffic Choices Study in Seattle met the base requirements for toll system operations. There remain issues that would need to be addressed in an actual implementation, but the Traffic Choices Study is a strong “proof of principle” from a technological standpoint, especially considering that the on-board units (OBUs) used in that study relied on technology that is now over ten years old.

An extremely important emerging realization (to which the Traffic Choices Study has contributed) is that the implementation of full network tolling is no longer fundamentally constrained

by technological limitations. The toll system elements implemented for the Traffic Choices Study met the base requirements for toll system operations. Indeed, it is technically possible to implement the same pricing policy principles within the highway realm that have, for so long, been in common use in virtually all other markets in the economy. This is not to say that there are no issues that need to be addressed in an actual implementation. But the Traffic Choices Study is a strong “proof of principle” from a technological standpoint. A set of system requirements developed for the Traffic Choices Study is included as Appendix B1-C.

More importantly, the technology being deployed for the Oregon Road Usage Charge Program meets all the basic requirements for a variable fee pilot program. Building on the implementation of the Road Use Charge Program represents a prudent approach to planning for the technical systems of a variable rate fee program as these technical systems will be proven and improved as a result of an extensive trial implementation period. As noted earlier the System Requirements Specifications (2012) and the Open System Architecture Model (2012) for the Oregon Road Usage Charge Pilot Program clearly provide for a set of technical and administrative systems that support an evolution in charging policy that includes the potential for fees that vary by time of day, location, and vehicle characteristics. The ability to support a fee program with vehicle positioning at its operating core is an important step in allowing an efficient fee demonstration to be a follow on to current efforts to transition to mileage-based highway finance.

### 6.3.1 On-board technologies

Transponders, also referred to as electronic tags, are the most common component of electronic toll collection in use around the world. Transponders are often mounted in the windshield of a vehicle, but may be located elsewhere in the vehicle.

Transponders are part of Automatic Vehicle Identification (AVI) technology that enables tolling facilities to accurately identify a specific vehicle at highway speeds. AVI technology also includes the use of a road-mounted or overhead gantry-mounted reader, which communicates with the transponder to identify the vehicle. As a vehicle passes under a toll-collection gantry, its electronic identification encoded into the transponder is sent to the gantry-mounted reader. The driver does not have to stop to pay the toll and no tollbooths are required. The vehicle identifier is sent on to a back-end toll collection system.

On-board GPS units (OBUs) monitor a vehicle's travel and calculate tolls from inside the vehicle, eliminating the need for installing expensive sensors on the roadway. This is particularly advantageous when applying tolls throughout a region, where it is not feasible to have ubiquitous, gantry-mounted sensors. The OBU uses signals from GPS satellites to determine the exact vehicle location and communicates with back-end systems through the cellular telephone network to learn of changes to toll rates and to communicate users' charges and account balances. The vehicles' locations are not transmitted, but may be temporarily stored within the OBU for verification purposes.

One of the advantages of GPS-based tolling is that this technology allows for more accurate time- and location-based tolls. Recent advances in GPS and related technologies allow for far more accurate identification of a vehicle's movement through a tolled area. GPS-based systems do have limitations, however. GPS systems rely on the vehicle's ability to receive satellite signals, which requires an unobstructed view of the sky. Recent advances in GPS-related technology take advantage of information from cell towers to estimate location, speed, and direction in the absence of satellite signals.

Mobile Enforcement Readers (MERs) are installed in enforcement vehicles. An MER unit allows an officer to read the transponders of passing vehicles or to travel adjacent to a vehicle in the HOT lane and read the transponder. The mobile unit provides the officer with the last date and time the transponder was read and whether the account is valid. This technology is used to ensure that users are not disengaging their vehicle's transponders as they pass under tolling gantries.

Some of the factors of importance when considering an efficient fee system technology will include the following:

- Functionality
- Privacy
- Auditability
- Reliability
- Cost

There are a variety of technical means through which mileage fees could be implemented. Any serious effort to account for vehicle

mileage must support independent validation of objective vehicle use information. A Nation Cooperative Highway Research Program report<sup>3</sup> developed by the RAND Corporation, as shown in Exhibit 6.3, itemizes the technical approaches to metering vehicle use, payment processing, managing enforcement, and protecting privacy.

In practical terms, actual revenue operations for efficient fee charging would require some automated system of cataloguing vehicle use either through a connection with the vehicle odometer and diagnostics port, or through exogenous means of vehicle identification and measurement of use such as GPS tolling devices.

*Supplemental On-road Devices*

Traffic sensor systems may be subsurface, roadside, or overhead. Inductive sensors embedded in the road surface can determine the presence of a vehicle. These sensors may be used to count the number of vehicles crossing a location as well as the number of axles in a vehicle as a vehicle passes over them. A two-loop sensor can also determine the speed of the vehicle passing over it.

Weigh-in-Motion (WIM) systems are capable of estimating the gross vehicle weight of a vehicle as well as the portion of this weight that is carried by each wheel assembly, axle, and axle group. WIM systems provide the date and time

**Exhibit 6.3. Potential VMT-Fee Implementation Options**

<b>Metering Options</b>	<b>Collecting Fees</b>	<b>Preventing Evasion</b>	<b>Protecting Privacy</b>
<ul style="list-style-type: none"> <li>• Odometer options:                             <ul style="list-style-type: none"> <li>- Self report</li> <li>- Required check</li> <li>- Assumed mileage with optional check</li> </ul> </li> <li>• Mileage estimates based on fuel economy and fuel consumption</li> <li>• Radio-frequency identification (RFID) tolling on a partial road network</li> <li>• On-board unit (OBU) options                             <ul style="list-style-type: none"> <li>- On-board diagnostics (OBD II) connection</li> <li>- OBD II / cellular</li> <li>- GPS</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Pay with registration</li> <li>• Pay at the pump</li> <li>• Wireless transmission to billing authority</li> <li>• Debit cards</li> </ul>	<ul style="list-style-type: none"> <li>• Odometer inspections</li> <li>• Odometer redundancy checks</li> <li>• Metering equipment checks</li> <li>• Default fuel tax payment</li> <li>• Fuel consumption redundancy checks</li> <li>• External wireless checks for functioning equipment</li> <li>• Device heartbeat signals</li> <li>• Device distress signals</li> </ul>	<ul style="list-style-type: none"> <li>• On-board data aggregation and fee computation</li> <li>• Anonymous proxy fee computation</li> <li>• Trusted third party</li> <li>• Prepaid debit cards</li> <li>• Anonymous user accounts</li> <li>• Encryption</li> </ul>

Source: Rand Corporation

of each vehicle passing over it, along with axle weights and spacings, vehicle classification, speed, and transponder ID, if the vehicle has a transponder. WIM systems allow participating trucks with transponders) to bypass weigh stations (e.g., “green light” programs).

License Plate Recognition (LPR) systems use video imaging and optical character recognition to determine a vehicle’s license plate number as it passes by the reader. LPR systems can be used to identify violators, apply tolls to vehicles that do not have transponders, and verify that transponders are in the vehicles they are registered to. LPR is the primary technology in use in the toll cordon area of downtown London.

Vehicle Occupancy Monitoring for managed lanes that allow exceptions to tolling for high-occupancy vehicles use infrared or visible light cameras to detect and count the number of occupants in a car. These systems suffer from both accuracy and privacy issues.

### 6.3.2 Back-end technologies

#### *Back-end systems and devices*

Back-end systems monitor and coordinate the information coming from on-road and on-vehicle systems. They may also archive such information for verification and auditing. In addition, back-end systems perform tolling-related calculations; manage user accounts, identification, tolling accounts, and transponder tag identification; and deduct tolls from users’ accounts. It is especially in the area of back-end systems that an efficient fee demonstration should build on the work undertaken by the Oregon Road Usage Charge Program.

In the U.S., several different companies manage tolling on highways in different states. Most of the northeastern states use E-ZPass, California relies on FasTrak, Minnesota uses MnPass, and Texas has TollTag, EZ TAG, and TxTAG. These last three are interoperable throughout the state. Interoperability among the several different tolling agencies across the country has not yet been achieved. In London and in Germany, a single tolling agency is responsible for operating and managing the tolling systems. In London, the cordon pricing is operated by Transport for London. In Germany, the Toll Collect system is ubiquitous in tolling heavy trucks for use of federal highways. Back office functions that were part of the Traffic Choices study are included as Appendix B1-D.

#### *Enforcement*

There are three common types of tolling-related violations: 1) failure to meet required vehicle-occupancy levels, 2) failure to pay a toll, and 3) crossing into or out of priced lanes where not allowed. The enforcement of vehicle-occupancy restrictions, such as in high-occupancy vehicle (HOV) lanes, can be difficult. Manual enforcement (wherein patrol officers are required to observe the violation, pursue the violating vehicle, pull the vehicle over to the roadside, and manually issue a ticket) can be labor-intensive, costly, and dangerous.

Tolled facilities, including tolled lanes and high-occupancy toll (HOT) lanes, have different options for enforcing toll collection. Toll lanes often enforce toll payment by detecting a transponder in the user’s vehicle. Violators may lack a working transponder, have an

invalid account, or have inadequate funds for the toll. Violations are captured by a video or photograph of the violator’s license plate.

### 6.3.3 Communication technologies and protocols

The most obvious approach to the data communication requirements of an efficient fee program is to employ standard cellular communication services. Due to the potentially high cost of these types of services there may also be opportunities to partner directly with data communication service providers. A discussion of communication requirement for the Traffic Choices Study is included in Appendix B1-D.

## 6.4 GEOGRAPHY

The geographic locus of an efficient fee pilot program would follow from the fee structure that is employed. As variable fees for road use by time of day and location will be a large component of the efficient fee, its demonstration will require a location that currently experiences some considerable congestion of the road system. Other factors that might influence the location of a demonstration include the budget available to cover a larger or smaller extent of the road network and its users. Budget for such a demonstration will be driven by participant costs (recruitment, management, equipment, and endowment) and will be somewhat linear with the number of participants. To the extent that sub categories of participants are to be examined independently the sample size requirements will increase which may limit the geographic extent of the experiment.

<sup>3</sup>NCHRP Report: System Trials to Demonstrate Mileage-Based Road Use Charges; RAND Corporation; Santa Monica, CA; 2010

The geography covered in a road use fee demonstration has implications for project design and budget. The following discussion of project geography is intended to provide sufficient understanding to allow for project planning and budgeting but final specifications about the geographic extent must be reserved for pre-implementation design. Three aspects of geography are covered below, fee coverage, road network details, and the geography of participant recruitment.

#### **6.4.1 Geographic Coverage of the Efficient Fee**

If participating vehicles are equipped with GPS enabled metering devices then there is essentially an unlimited geographic extent of the efficient road use fee demonstration within the state of Oregon. In other words wherever a participating vehicle is driven there is a corresponding record of mileage. The design question for the project will which taxing jurisdictions to represent within the tariff model functions of the back office. As a practical matter it should be a fairly simple process of establishing geographic entities to include in a tariff model, and not prohibitively difficult to support the accounting of road use fee revenues for additional taxing jurisdictions, should this be desirable. Taken together these considerations support a geographic coverage that represents independent taxing jurisdictions that include the state as a whole and potentially counties should local option taxes be envisioned.

#### **6.4.2 Road Network Detail**

There are at least two independent means of measuring vehicle mileage with GPS enabled

metering devices. The first is a simple Euclidean measure of distance covered between GPS waypoints. Any arbitrary set of waypoints can be summed to provide a total distance between points of interest. The second approach takes the raw GPS waypoints and employs a method for matching those points to a digital map representation of a road network. Once GPS records are matched to the road network it is the attributes of that road network that provide a measure of the distances that are covered. It is likely that for any mileage fee program both methods will be employed in some form. For example, vehicle mileage might be totaled as a product of simple Euclidean distance between GPS waypoints but a geo-gate (a cut point on a digital map) would signal the traverse between two counties. In the case of a fee that varies by facility (e.g. urban freeways during peak travel periods) each road segment would be have a corresponding digital representation as a component of a charged network. Since measuring the Euclidean distance between GPS waypoints introduces no particular design constraint on the project it is useful to consider more closely the requirement to develop a digital map of the parts of the road network that have unique charges associated with them.

A variable mileage fee is likely to involve fees that vary by facility and time of day, but only in cases where there is some significant congestion present on the road. Rural roads and local collectors are unlikely to fit this definition. As a result the extent of the road network that needs to be part of a digital network is fairly modest. Many forms of digital maps or road

networks currently exist, and many are open source. The form of digital map that is best for this project will depend on the approach to map matching that is employed. All of these details are best left open until a technology vendor is involved in the final design effort. If digital maps, and map matching algorithms, are only required for use in the back office then there are likely no constraints on the size of the road network that can be used. If map matching must occur in the in-vehicle metering device then storage limitations of these devices may present some upper bound on the size of the road network. For all the above reasons it is useful to consider limiting the network of uniquely priced facilities to urban freeways and arterials.

#### **6.4.3 Participant Recruitment Geography**

The design requirements that the sample protocol introduces are discussed more in the next section, but the geography of the sample is one important consideration. The participants in the demonstration project should generally reside and work in the geography in which the fee is being implemented. Since participant management is a potentially costly exercise the sampling geography should be as centralized as is feasible given other project design objectives. Minimizing the costs of communicating and coordinating with participants is a very important part of managing overall project costs for this type of demonstration. Other aspects of the sample design, such as sample enrichment discussed below, also argue for an oversampling of the urban population.

## 6.5 EXPERIMENTAL DESIGN

### 6.5.1 The design of a demonstration follows from its objectives

A brief examination of the approach to experimental design employed during the Traffic Choices Study in Seattle help to illustrate how important it is to have clarity on study objectives. A similar example is the recent design of the Oregon Road Usage Charge Program; which is well documented and understood by authorities in Oregon.

In the spring of 2003, the Traffic Choices study team began designing an experiment that would require a highly technical simulation of a toll system. The project had a limited budget to create the technical system, yet it needed to support the highly detailed behavioral experiment. The technical system needed to meet a variety of requirements, including:

- Represent a high degree of roadway network detail
- Provide a highly flexible toll schedule
- Assign road users to roads used accurately
- Handle all transactions in a verifiable manner
- Provide direct feedback to the road user about facility use and tolls
- Support behavioral analysis with flexible system for storing participant data
- Provide toll system billing functions
- Equip all participating vehicles with meters, and uniquely identify all those vehicles
- Function without permanently altering participant vehicles

- Support operations with little or no testing
- Meet the project budget

The project team selected the GPS tolling approach because it offered a ubiquitous and cost-effective method of tolling on all roads. By relying on “in-vehicle meters,” the team avoided the need for expensive wayside antennae. GPS allowed for cost-effective tolling of arterial roads, important in the Puget Sound region where the extensive highway network makes selective tolling pilots difficult to implement. GPS technology also has valuable future implications: as vehicle technology changes, it could become a replacement for the existing tolling of roads using fuel taxes.

The toll system needed to handle complex trip characteristics and tolling strategies. In short, it had to be very accurate about where and when vehicles traveled (high precision waypoint locational capability and high frequency waypoint capture capability). In addition, the OBUs needed to be able to communicate user fees to participants as they were incurred, including total trip costs as well as toll rates per mile. They needed to include the capacity to communicate eight to ten different price levels (for different time periods or facility characteristics) and reliably price the over 7,000 road links in the regional network.

The measurement of trips, vehicle miles traveled (VMT), trip purpose, route, origin and destination locations, and so on would be determined, in part, by analyzing the data once the trips were completed. Because daily travel behavior naturally has a large variance, the quality of the data had to be high so as to not introduce

spurious variation with missing or imputed data. Because behavior changes measured in this study would be subtle or marginal, losing or misinterpreting data had high costs, so reliability was a critical requirement for the selection of the system for the data retrieval and processing.

While the project team was defining the technical requirements of the system and acquiring a vendor to provide such a system, it was also refining all other aspects of the experiment. The team created requirements for the sample to ensure the findings could be generalized to a broader population of road users, and determined toll rates to closely approximate the short-run marginal costs associated with the use of various elements of the road network. It developed a participant recruitment and management plan, and established a basic methodology for creating household travel budgets (endowment accounts). In summary, the study went through the steps shown in [Exhibit 6.4](#) (on the following page) before implementation.

### 6.5.2 Must also meet scientific standards for validity of results

Pilot projects that aim to understand consumer behavior must also adhere to scientific standards that allow for useful analysis to be performed at the conclusion of the study operation. Sample size is a key issue for any experiment. The sample for a study of road users should be grouped by households, as many households have multiple vehicles. A large sample is always preferred (everything else being equal) to a smaller sample. As a practical matter, however, the advantages of sample size

**Exhibit 6.4 Design and Implementation Steps**

5/1/2003	Developed approach to toll system vendor procurement
9/1/2003	Issued request for qualifications from System Integrators (toll technology)
10/20/2003	Received System Integrator submittals
11/15/2003	Selected of Siemens as System Integrator
2/5/2004	Held initial design workshop with Siemens
4/1/2004	Signed Siemens contract
4/1/2004	Finished sample design and participant recruitment planning
5/1/2004	Started tolling road network development (geography and road classes)
7/1/2004	Started road digital map file (geo-data) development process
7/1/2004	Started project communications material development
9/21/2004	Started participant recruitment
9/30/2004	Completed back office functionality
10/20/2004	Completed initial participant recruitment
10/20/2004	Completed tolling network geo-data
10/28/2004	Achieved passage of the system Acceptance Test (Siemens)
11/8/2004	Began installation of On-Board Unit (OBU)
11/30/2004	Began second participant recruitment phase
1/1/2005	Finished tariff model - toll rates
2/10/2005	Completed second phase participant recruitment
2/20/2005	Completed OBU installation
3/1/2005	Began baseline data collection

Source: Puget Sound Regional Council, ECONorthwest

must be balanced against the disadvantages of measurement error if sample size is gained by using a primitive data collection technology. Holding the methods and precision of data collection constant, a larger sample means larger costs due to the requirements of equipping all household vehicles with charging

meters and funding their travel budgets. For all of these reasons, it is generally better to have high-quality data from a smaller sample than lower-quality data from a larger sample. But each pilot project is unique and will introduce its own sample and analysis requirements. Behavioral experiments must consider experimental protocol, control for self-selection bias, and may require an enriched sample approach. All of these factors interact with the sample requirements. The approach taken for the Traffic Choices Study is outlined in [Appendix B1-E](#).

**6.6 MANAGEMENT OF THE DEMONSTRATION**

A variable rate road fee pilot project will be a complex undertaking and require a strong operational partnership from key stakeholders. These key stakeholders include Metropolitan Planning Organizations, various departments of the State of Oregon (at a minimum ODOT but possibly including other departments responsible for revenue collection, vehicle licensing, and enforcement), and the Federal Highway Administration.

Regional planning bodies are locally based and have direct access to other local taxing jurisdictions. The State of Oregon should provide oversight and guidance related to statewide interests and policies as well as address coordination across the various state agencies. The Federal Highway Administration has a particular interest in road fee programs and addressing some degree of standardization across various states involved in testing these programs. The funding of a significant demonstration project will also require funding

contributions from a broad array of partners. There are many ways to structure a partnership and this paper does not attempt to posit what approach will best meet agency and stakeholder needs in Oregon.

The recent organization of various parties interested in mileage fee programs under the Mileage Based User Fee Alliance offers another opportunity to learn from related efforts, clarify design and demonstration project objectives and identify common areas of practice that need attention. The Alliance represents a coming together of a number of States as well as vendors and researchers in the market.

It is also true that the operation of a variable fee demonstration will require the partnership to be extended to private vendors in order to get the best value from the program operation. The key to the effective management of vendor participation is a clear division of responsibilities that is guided by the particular strengths of each party. A variable fee demonstration involves developing and deploying a system of systems with functional dimensions that include in-vehicle hardware for positional locating, telecommunications, back office and data management, account management and bill processing. It is probably clear that private vendors will take a lead role in some aspects of the project, for example the mileage fee recording devices installed in the participant vehicles and telecommunication services. But private vendors may be required in other aspects of operations. The current concept-level planning of a demonstration is not the right time to determine roles and responsibilities but early design work on the implementation of the

demonstration project must get detailed enough to provide clarity on which parties are best positioned to take on what roles. It is necessary to do this work in advance of going out into the market to secure private vendor products and services.

There are many approaches to securing and managing vendors, and generally managing the risks associated with project implementation. One approach is to contract for services with performance targets rather than products that meet specifications. Another approach is to develop open standards around how technical aspects of the project will operate and then invite any vendor that can meet those standards to participate in the project. Invitations to participate can be extended to any vendor with off-the-shelf technology as a means of keeping costs down and minimizing the risks associated with technology development efforts.

#### **6.6.1 Budget is a function of the design details and approach to partnering with potential vendors**

The largest costs for an efficient fee pilot project are likely the costs to implement the technical systems that levy charges and collect behavioral data. Once again it is worth pointing out that building on the approaches taken for the Oregon Road Usage Charge Program can yield significant cost advantages over designing a system from the ground up. Other costs associated with a behavior experiment might include higher costs for participant management, funding travel endowment accounts (should this be included in the experimental design), and the costs of

behavioral analysis at the conclusion of the pilot operations. When the Oregon Road Usage Charge Program is significantly underway it will be feasible to develop a more detailed estimate of the costs to implement a variable rate pilot.

Based on the implementation of the Traffic Choices Study in the central Puget Sound region, and other related projects (ODOT, Netherlands) it is possible to develop a preliminary sense of the implementation costs. Pricing for hardware, software, and the telecommunication services required for a mileage fee demonstration changes quickly. A more comprehensive review of recent efforts at implementing mileage-based user fees should be undertaken during the pre-design phase of the project and used to refine budget details in advance of contracting for any required services.

One important goal of demonstration projects is to minimize risk associated with the full implementation of complex programs. But any large-scale demonstration project will itself include risks. The primary risks in such programs are to the budget and schedule. Early design work on the implementation of the project should involve an identification of specific risk factors, and strategies to minimize and manage those risks.

A planning budget should incorporate some risk management even at this early stage in planning. Key aspects of the budget about which there is uncertainty can be estimated using information on cost probabilities. A budget rollup can then use Monte-Carlo simulation techniques to develop expectations about total

project cost. A pilot project with a two-year duration and involving around 1000 participants might cost between \$3 million and \$4 million. There may be possibilities for cost savings, but it is unlikely that the project, as specified, could be done for as little as \$2 million. Similarly, the estimates are based on an actual study that is similar: they are unlikely to be more than 50% too low, so it is unlikely that the project would cost more than \$5 million.

## **7. NEXT STEPS**

A well-designed demonstration of variable fee is major undertaking technically, politically, and financially. This kind of effort progresses incrementally. This paper is one first step. The next step would be to build upon the success of current efforts to implement road usage charges in Oregon. Additional steps toward a practical implementation of a pilot project involve developing clear objectives, coordination with other entities and interests and securing the appropriate authorization and funding.

### **1. Demonstrate variable rates by building on the success and technical implementation of the current mileage fee program**

The implementation of a variable rate pilot project needs to be distinct from the mileage fee program but also take advantage of opportunities to build on the systems and practice put in place to support that program, especially back office systems, enforcement and payment processing. The goal should be to build on success but not interfere with, or complicate, the ongoing implementation of an operational program.

## 2. Develop a clear message that explains why a pilot project is useful

ODOT's report on the outreach involved in their Tolling and Pricing stakeholder process (*Tolling and Pricing Stakeholder Involvement Summary and Recommendations*) was clear on the importance of developing an understandable message about where policy is heading and why. The report states: "ODOT should prepare to deliver messages that thread these various technical and methodological issues together into a more comprehensive story as part of a broader public education and involvement process." Developing a message begins by agreeing on, and finalizing, a set of objectives for the pilot project. Potential objectives are discussed in section 6.1.2. With a project of this complexity and potential sensitivity it will be necessary to develop a strategic communications plan that identifies core messages and tactics for forming expectations and presenting information about the project to stakeholders and the public. The message should be about an efficient operation of an overall road management and investment program, not just about the need for revenues.

## 3. Include local governments and MPOs in planning

Many of the cost associated with road use such as congestion and road wear and tear occur on infrastructure managed by local government agencies. Congestion, in particular, is largely an urban phenomenon. Close coordination with local entities involved in road system management will be critical to the success of a variable rate road use fee pilot project. Regional

planning organizations are locally based and have direct access to other local taxing jurisdictions and as such are one effective means for coordinating with a large number of individual jurisdictional interests.

## 4. Secure authorization and funding

Appropriate authorizations and funding will need to be secured before a pilot project can be initiated. Authorization should include specific directives to state agencies and provide general guidance on pilot project objectives and desired outcomes. Since there is an opportunity to build on, but not interfere with, the work of the Oregon Road Use Charge Program authorization and funding should be secured in a time frame that will allow the pilot to begin operations by around 2017.

## 5. Ensure accountability with clear expectations about results

Conducting pilot projects is a prudent means of testing potentially complex and costly changes in policy. To get the most out of a pilot test it is important to specifying the results that are desired. Expected results should tie clearly back to the objectives of the project. Pilot project authorization should clearly state the desired results of the program while providing sufficient flexibility in program operations. The promise of a variable mileage fee is that many of the most difficult aspects of surface transportation management are improved considerably. These management challenges relate to cost recovery (revenue), fairness, pollution, and congestion externalities. Each of these can be improved upon through the implementation of road usage fees that 1) more closely reflect the costs that users impose and 2) facilitate better

asset management practices amongst road authorities. Even as long-term benefits from an efficient fee program are clear and large in scale the challenges for implementing such a program are many. Such a fee represents a large-scale change from existing policy and would involve disruptive transformation in many aspects of surface transportation management and operations. Demonstration projects offer an opportunity to gain insights into how to design a program and how to respond to challenges without making the commitment of a full-scale implementation. The pilot project proposed here should be expected to generate significant contributions to the knowledge about mileage-based user fees across a broad range of important topics, including:

- Accounting for Driver Behavior
- Testing the technical and operational systems
- Safeguarding Privacy
- Understanding Fairness

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## APPENDIX BI-A: TRAFFIC CHOICES STUDY ANALYSIS OF BEHAVIOR

The basic analytical approach to understanding behavioral response to tolls involved estimating linear *impact* regressions with observed dimensions of travel demand (across households, vehicles, and workers) as dependent variables, and with measures of the generalized costs of travel (tolls, out-of-pocket costs and time costs), household demographics (income and number of drivers), seasonal factors, and a measure of transit viability as explanatory, or independent variables.

### THEORETICAL EXPECTATIONS

The imposition of tolls where none had been levied before will raise the perceived cost of travel, everything else being equal. We will call this initial effect the impact of the tolls and the associated generalized costs. It is the initial effect because we expect the traveler to respond to the tolls' effect on generalized cost. Since the demand for travel is a derived demand from the desire to perform other activities (working, shopping, sightseeing, etc.), the higher generalized costs impair the utility of the primary travel purpose. Consequently, theory suggests that the traveler will seek ways to mitigate this impact, so as to preserve as much as possible of the value ("utility") of the primary purpose of the travel.

There are numerous ways that the traveler can respond to the increase in the generalized cost of travel. In the short-run, the traveler can:

- Travel by alternative paths to reduce the increase in generalized cost. Some paths, though involving longer travel times, may offer sufficiently lower tolls that generalized costs are reduced.
  - Change the number of times that the affected tours occur. If the traveler has the opportunity to work at home or consolidate multiple tours into a single tour, total generalized costs per period may be reduced below the initial tolled level.
  - Select another mode of travel. If transit service is available, or if the traveler can form and use a carpool cost-effectively, the generalized cost of the travel may be able to be reduced below their impact level.
  - Travel at a different time. Since the tolls in the experiment varied by time of day (to approximate the variable burden of travel at different times on regional road capacity), there may be opportunity to make tours at alternative times.
- In the longer run, travelers can make other choices that can economize on the generalized costs of travel. The experiment was not expected (by participants) to be long-term, so the incentive to make such adjustments was not strong. However, for completeness, it should be said that, with a permanent tolling program, one might expect travelers to:
- Change the locus of employment, residence, or both.
  - Make changes in the time or path of travel, as a consequence of re-negotiated workplace and residence choices.
  - Change the vehicles used for travel to economize on operating costs or to provide higher amenities to offset the costlier travel.
  - Thus, we expect the effect of the tolling to be some combination of the following:
    - Reduce the number of auto tours, either through tour suppression or through changes in mode.
    - Increase the number of trip segments per tour to economize on the total cost of travel across all travel purposes.
    - Reduce the amount of tolls paid per tour relative to the impact toll level per tour.
    - Alter the time of travel in favor of lower-toll times of travel.
    - Alter the path taken, with attendant changes in distance traveled and time spent traveling. Depending upon the opportunities available to change paths, modes and the time of travel, the duration of travel and distance traveled per tour may either increase or decrease.
- For any given tour purpose, the response may be different from that postulated above since the household likely considers its costs and opportunities of travel in an integrated fashion. That is, it may be able to offset the toll impact of, say, the home-to-work tour by modifying the work-to-home tour, or work-to-work or home-to-home tours. Similarly, impacts on one household member may be able to be offset by changes in behavior of other household members. The less integrated is the household's thinking (or the greater are the constraints on integrated planning), the less likely are such accommodations.

Across households of various demographic characteristics, we generally expect:

- The response to tolls to be less responsive (“elastic”) for higher income households. The theoretical logic here is that such households have less binding household budget constraints and higher utilities associated with the primary purposes of travel.
- An ambiguous relationship between travel response and the number of drivers in the household. On the one hand, the greater the number of drivers the higher the probability that cost-effective carpooling can be implemented. On the other hand, the coordination or integration of a household level response may be made more complicated by the diverse travel purposes and opportunities across members in the household.
- Households with more viable transit options to display more toll-elastic behavior regarding auto tours, drive time and distance traveled, at least in the home-to-work and work-to-home periods.

The Travel Choices Study, and the high-resolution data it yielded, is a unique data resource. As such, it permits examination of dimensions of response (such as trip chaining) that are impossible to study well even with large, household survey instruments. Unlike such instruments, the Travel Choices data instrumentation persisted for more than a year, permitting observation of even statistically-rare travel events. On the other hand, large

cross-sectional household surveys, though reporting data from shorter periods of observation, are better sources of long-run adjustments to changes in generalized costs of travel.

In this regard, it is useful to consider the results reported herein with those summarized in recent state-of-the-practice reports that use the household panel method. One such useful summary of the disaggregate modeling of urban travel demand is offered in Daniel McFadden’s, *Disaggregate Behavioral Travel Demand’s RUM Side A 30-Year Retrospective*.<sup>1</sup> As that report suggests, there is reasonable consistency in the findings regarding the coarser dimensions of travel behavior (such as revealed values of time), but less reliable insights regarding such things as the time of day of travel and trip chaining behavior.

### MEASURING TRANSIT VIABILITY

The study’s household sampling methods were designed to enrich the sample for households located in proximity to available transit services. Households on the recruiting call list were assigned a dummy variable for transit “viability.”<sup>2</sup> However, since there was no way of knowing common trip destinations for household members, and due to the limits of the household recruitment call list, the enrichment process did not produce a household measure of transit “viability” ideal for inclusion in the econometric analysis. At the conclusion of the experiment it was possible to unambiguously measure the usefulness of available transit services

between specific, and frequently paired, origins and destinations. This analysis was limited to household vehicle trips that were associated with the household work locations. In this case, a transit “viability” function was estimated as the ratio of auto and transit generalized costs (time and cash costs) associated with each origin and destination zone in a base year run of the region’s travel demand model. A continuous measure of transit “viability,” tied directly to actual household-level travel patterns, permitted analysis of the relative importance of work trip transit service availability (worker models only) to the behavioral response of the participants when faced with tolls on the roadways.

Empirically, we estimated the probability of a household utilizing transit for their home-to-work commute through the following two steps:

1. We computed the difference between the estimated generalized cost of commuting by auto and the estimated cost of the same commute by transit. The generalized cost of the auto commute is composed of the individual’s value of time plus the operating cost of the vehicle. The generalized cost of the transit commute is composed of the individual’s value of time cost for each component of the transit trip (walk time, wait time, boarding time, and in-vehicle time) plus the cost of the transit fare.<sup>3</sup> With only a few exceptions, this difference (auto VOT minus transit VOT) was typically negative. That is, the generalized cost of transit was higher—often much higher—than the generalized cost of commuting by auto.

<sup>1</sup><http://elsa.berkeley.edu/wp/mcfadden0300.pdf>

<sup>2</sup>Transit “viability” was estimated from the regional travel demand model, where for each transportation analysis zone, the weighted average of transit travel times were computed between the zone and all other zones.

<sup>3</sup>It is widely recognized that value of time differs between auto and transit commuting and differs among the components of transit commuting, with in-vehicle transit value of time being significantly lower than the value of walk time, wait time, and boarding time. Value of time of auto driving is approximately mid-way between in-vehicle transit value of time and the value of time of the other components. These differences in value of time are accounted for in the analysis.

2. The differences in generalized cost of commuting by auto vs. commuting by transit, which range from as high as \$0.61 to as low as -\$76.93, are positively correlated to the probability of choosing transit over auto. For those individuals where the VOT of commuting by auto or transit is approximately the same, other studies have found the probability of taking transit to be approximately 30%.

3. For those individuals where the generalized cost of transit is higher than the generalized cost of commuting by auto, the probability of taking transit is much lower. In order to convert the differences in generalized cost, estimated in step 1, into estimates of the probability of taking transit, they are first rescaled so that the differences vary between \$0.00 and -\$20.00. The rescaled differences were then hypothesized to be approximate equivalents to utility log-sums and were converted into transit accessibility probabilities using logit transformation arithmetic:

$$4. \quad P(\text{transit}) = \frac{1}{(1 + e^{-z})}$$

where  $P(\text{transit})$  is the probability the commuter will use transit and  $Z$  is the hypothesized log likelihood ratio.

The result of this exercise, is an estimate of the viability of transit as an alternative to auto commuting. Consistent with the earlier studies, the estimates of the probability of taking transit during work-related travel are conservatively truncated at 0.40.

### INCONSISTENCY WITHIN HOUSEHOLDS

Existing evidence and theory suggest that, all else being equal, when faced with higher tolls to use a network of roads facilities motorists will not choose to drive on those toll roads more than they would when no tolls are present. A select group of study households violated this expectation over the 18 months of the study's operation. There are a number of potential reasons why households would behave in a manner that appears to be internally inconsistent when viewed from the perspective of the experimental observer. First, we need to establish the conditions under which a household is considered to have been behaving in a way that is internally inconsistent. When faced with higher tolls (in this case any tolls) on the road network, these households both incurred higher toll costs than their control driving would have incurred, and they drove more or longer distances. Essentially, these households exhibited upward sloping demand curves and negative values of time. These households were flagged and assigned a dummy variable during the econometric analysis. This dummy term was interacted with other explanatory variables.

Specifically, a household was flagged if:

- (a) The average weekly tolled miles it drove during the experimental period was greater than the average weekly miles it drove during the control period, and
- (b) The average weekly minutes it drove during the experimental period was greater than the average weekly miles it drove during the control period.

The possible reasons for why a household might behave in such a manner are numerous, and are expected to occur during a lengthy social experiment such as the Traffic Choices Study. Changes in home, or work locations, the presence of an additional driver in the household, any new non-discretionary need to frequently use a household vehicle could cause results that are inconsistent with economic theory and common sense. If these changes are observed they can be accounted for in a manner that brings the observed behavior back in line with theory. The project went to great lengths to minimize the effect of these events on the experimental data. First, households were screened during recruitment, asked about the likelihood of major life changes occurring over the following two years. Household vehicle use patterns were monitored over the course of the project, where households were contacted when anomalous patterns (such as vacation related inactivity) emerged. Households were also surveyed at the conclusion of the study to determine if any number of major household changes did happen during the course of the data collection period. All these measures were, of course, insufficient to ensure that all causes of seemingly anomalous behavior were accounted for.

### THE IMPACT MODEL METHODOLOGY

There are numerous methods that might be used to measure behavioral responses to tolls. In this study, behavioral responses were measured using what will be referred to as the impact model approach. Specifically, in keeping with the experimental nature of the data, the

behavior of individuals is measured relative to the behavior they exhibited in the control period.

In the impact model approach, the behavioral changes are measured relative to what the presumed behavior would have been “but for” the imposition of the experimental tolls. We wished to facilitate measurement of arc elasticities and to avoid the econometric hazards of endogenous right-hand-side (RHS) or “independent” variables. Thus, the experimental toll treatment is the toll that would have been paid (computed using control period behavior), but for their response to the experiment. That is, the toll actually paid (which is a variable that is endogenous to the experiment), is not used as a RHS variable, but, in fact, studied as an impact or dependent variable.

The general econometric formulation of the impact equations follows from specification of a general behavioral relationship, and its transformation into an experimental minus control, impact formulation:

$$Y_i = \alpha + \beta X_i + \varepsilon$$

$$\Rightarrow \Delta Y_i = \beta \Delta X_i + \varepsilon$$

where :

$Y_i$  = a measure of travel behavior, e.g., number of tours per week

$X_i$  = a vector of measures of traveler and travel cost indicators expected to influence behavior

$\Delta Y_i = Y_i^e - Y_i^c$  = experimental minus control behavior

$\Delta X_i = X_i^e - X_i^c$  = experimental minus control conditions

The general behavioral formulation can be through of as the demand for, say, tours as a function of the X-vector of traveler and travel cost indicators. The impact formulation

reformulates the econometric model to a difference or delta model. Note that his eliminates the intercept (alpha) term in the general, behavioral model. This eliminates a parameter from the model, which is advantageous from the standpoint of the degrees of freedom available in a limited sample-size setting, but, of course, also means that the underlying behavior model itself cannot be completely characterized.

This general formulation is not a constant-elasticity model. However, the arc elasticities (i.e., the elasticity measured at variable means) can be calculated. Assume, for the sake of this discussion, that there is only one RHS variable comprising the X-vector, say, the generalized cost of travel. Once the difference model is estimated on the data, the elasticity of Y with respect to X can be calculated as follows:

$$e_{X}^Y = \left[ \left( \frac{\Delta Y}{Y_c} \right) / \left( \frac{\Delta X}{X_c} \right) \right] = \left[ \left( \frac{\Delta Y}{\Delta X} \right) / \left( \frac{Y_c}{X_c} \right) \right]$$

$$= b X_c / Y_c$$

where :

$b$  = the estimated value of  $\beta$

The implied elasticity is dependent upon the estimated coefficient, and the values of X and Y used to solve the elasticity formulation. In the presentation above, it is assumed that the control period values are used; alternatively, the experimental equilibrium values can be used. The implied elasticity will vary slightly with the values employed.

The actual empirical formulation was elaborated to permit traveler characteristics to influence the

computed elasticity. This results in the general formulation:

$$Y_i = \alpha + (\beta_0 + \beta_1 H_i) G_i + \beta_2 H_i + \varepsilon$$

$$= \alpha + \beta_0 G_i + \beta_1 H_i G_i + \beta_2 H_i + \varepsilon \Rightarrow$$

$$\Delta Y_i = (\beta_0 + \beta_1 H_i) \Delta G_i + \varepsilon$$

where

$H_i$  = a vector of household characteristics

$G_i$  = generalized cost of travel

= vehicle operating and travel time costs + tolls

=  $O_i + P_i$

This formulation allows the elasticity of Y to be measured with respect to generalized costs, G, and tolls, P, once the delta formulation is estimated using sample data. The computation of these elasticities proceeds as follows:

$$e_Y^G = b G_c / Y_c$$

$$e_Y^P = \left[ \left( \frac{\Delta Y}{Y_c} \right) / \left( \frac{\Delta P}{P_c} \right) \right] \approx b (\Delta P / G_c) (G_c / Y_c)$$

where

$b$  = the estimated value of  $(\beta_0 + \beta_1 H_i)$

Because there is, technically, a zero control period toll, the toll elasticity measure can be measured only at the equilibrium toll, not in the control period. However, the general implication of these computations is that the elasticity of Y with respect to tolls, P, will be lower (in absolute value) than the elasticity with respect to generalized cost. Specifically, the elasticity will be different by a proportion approximately equal to the ratio of tolls as a share of total, generalized cost in the final equilibrium. Separate econometric exercises were performed that suppressed the non-toll deltas in generalized cost. Since, the only realm for

exogenous change in generalized costs (other than tolls) is the inadvertent “experimental” effect introduced by changing (market) fuel costs, toll elasticities also could be measured directly by suppressing these other exogenous effects. In either case, the most meaningful elasticity is the generalized cost-based elasticity because of the theoretical and empirical issues surrounding the measurement of toll elasticities directly. The discussion that follows describes the variables employed in the econometric exercises.

**DEPENDENT VARIABLES**

All trip records were associated with one vehicle and each participant household was associated with one of more vehicles, and all trips linked to a work location were associated with a working household member. As a result, regression models were developed to explain household, vehicle, and worker demand response to tolls. Trip data for households, vehicles, or workers was assembled into weekly measures of trip making behavior, such as the number of tours (per tour type) made each week of the study. These measures of travel demand were the dependent variables in the linear modeling. A table follows ([Exhibit A.1](#)) with mean values of these dimensions of demand at the household-level for the data collected during the project’s non-tolled control period.

The dependent variables included:

- Number of Tours
- Tour Distance
- Tour Drive Time
- Trip Segments

**Exhibit A.1. Mean Values for Dependent Variables**

**Household Mean Values of Dependent Variables (Control Period)**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Tours Per Week	4.46	4.46	9.04	2.26	18.65
Tour Distance	11.99	13.78	11.74	5.15	11.31
Tour Drive Time	23.28	30.10	27.03	13.13	25.26
Trip Segments Per Tour	1.08	1.40	2.19	1.42	1.71
Tour Tolled Miles	9.17	10.56	8.12	3.55	8.28
Tour Tolled Cents Paid	235.73	282.43	122.01	53.71	171.40
Tour Start Time	8.65	16.54	14.37	12.78	13.38

**Vehicle Mean Values of Dependent Variables (Control Period)**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Tours Per Week	2.51	2.54	6.07	0.92	11.96
Tour Distance	11.84	13.63	11.33	5.68	11.46
Tour Drive Time	23.54	30.20	25.97	14.81	25.05
Trip Segments Per Tour	1.27	1.68	2.27	1.71	1.72
Tour Tolled Miles	9.02	10.34	7.85	4.10	8.41
Tour Tolled Cents Paid	221.87	265.23	119.93	64.93	185.19
Tour Start Time	9.02	16.30	14.39	12.77	13.34

**Workplace Mean Values of Dependent Variables (Control Period)**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Tours Per Week	3.49	3.54	NA	1.32	NA
Tour Distance	12.11	13.86	NA	5.93	NA
Tour Drive Time	24.08	30.63	NA	15.15	NA
Trip Segments Per Tour	1.28	1.60	NA	1.72	NA
Tour Tolled Miles	9.32	10.73	NA	4.27	NA
Tour Tolled Cents Paid	229.37	281.29	NA	71.54	NA
Tour Start Time	8.94	16.49	NA	12.74	NA

- Tour Tolled Distance
- Tour Start Time, and
- Tolls Paid

The table displays mean values for dependent variables on a per tour basis (which aids intuitive interpretation), while the impact models that follow explain changes in the demand variables on a per week basis (weekly measures produced the most stable models).

**EXPLANATORY VARIABLES**

The Traffic Choices Study was primarily a study of the behavior of drivers in response to paying tolls for the use of the road network. It follows that the primary explanatory factor in the modeling of travel demand behavior was delta **general costs**, which is a measure of the incremental change in the cost of the tour between the control and experimental period. Delta general costs is composed of the toll cost that *would be* assessed on the typical tour route taken by each household during the control

period (but for it being the control period) plus an estimate of the incremental change in the vehicle operating cost between the control and experimental period.<sup>4</sup> Other important explanatory elements that were included in the modeling were household income, the number of drivers in the household, dummy variable for summer weeks, measures of transit accessibility for each household (described in more detail above), and a dummy variable for households that exhibited highly anomalous behavior in response to the toll “treatment” (also described more above). Also included were interaction terms where the household dummy was interacted with other primary explanatory variables. Below is a table with mean values for explanatory variables for each of three levels of analysis focused on the household, the vehicles, and workers respectively. In each case mean values are provided for each tour purpose (Exhibit A.2).

**SHORT-RUN PRICE ELASTICITIES OF DEMAND**

Primary findings from the study record the magnitude of the short-run travel behavior response to tolls, across a broad range of behavioral dimensions. Short-run elasticities of demand were estimated for models explaining household, vehicle, and worker behavior independently. Models were estimated explaining behavior in regard to changes in generalized costs of travel and are reported in regard to the changes in toll costs. As stated previously the elasticities with regard to generalized costs are the most meaningful. However the elasticities with regard to toll

**Exhibit A.2. Mean Values for Explanatory Variables**

**Household Mean Values of Explanatory Variables**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Toll Costs	233	278	121	66	171
Dum HH	0.327	0.327	0.327	0.327	0.292
Dum HH * Delta Toll Costs	73	87	36	22	44
Transit Access * Delta Toll Cost:	83	105	46	22	67
HH Income * Delta Toll Costs	19,376,925	23,002,583	9,430,299	5,159,637	13,259,877
HH Drivers * Delta Toll Costs	396	468	199	108	275
Summer Dummy	0.275	0.275	0.275	0.275	0.275

**Vehicle Mean Values of Explanatory Variables**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Toll Costs	222	265	120	65	185
Dum HH	0.353	0.247	0.352	0.322	0.296
Dum HH * Delta Toll Costs	83	70	36	10	52
Transit Access * Delta Toll Cost:	70	89	40	21	62
HH Income * Delta Toll Costs	20,313,347	24,006,097	10,081,247	5,596,941	16,090,817
HH Drivers * Delta Toll Costs	412	486	217	113	330
Summer Dummy	0.275	0.275	0.275	0.275	0.275

**Workplace Mean Values of Explanatory Variables**

Variable	Home-to-Work	Work-to-Home	Home-to-Home	Work-to-Work	All Tours
Toll Costs	229	281	NA	72	NA
Dum HH	0.396	0.266	NA	0.396	NA
Dum HH * Delta Toll Costs	90	75	NA	31	NA
Transit Access * Delta Toll Cost:	10	12	NA	3	NA
HH Income * Delta Toll Costs	20,345,065	24,686,856	NA	5,931,561	NA
HH Drivers * Delta Toll Costs	412	508	NA	117	NA
Summer Dummy	0.269	0.269	NA	0.269	NA

costs (illustrated in tables and figures below) may be more intuitively understood as they can be interpreted as direct estimates of the actual magnitude of changes in behavior. In other words, if the elasticity of tour distance is reported as -.12, this can be thought of as estimating a reduction in tour distances of 12 percent across the sample of households. Also, none of the elasticities need to be factored together to interpret findings, they can be thought of as total derivatives. The models were developed in such a way as to ease the process

of making sense of the direct results of the analysis.

**Household, Vehicle, and Workplace Models**

Analysis of the impact of tolling on driving behaviors was conducted from three separate perspectives: the household, the vehicle and the workplace. The reason for conducting the analysis from the different perspectives was to examine the extent to which behaviors differed under different units of observation. We consider the household to be the baseline perspective

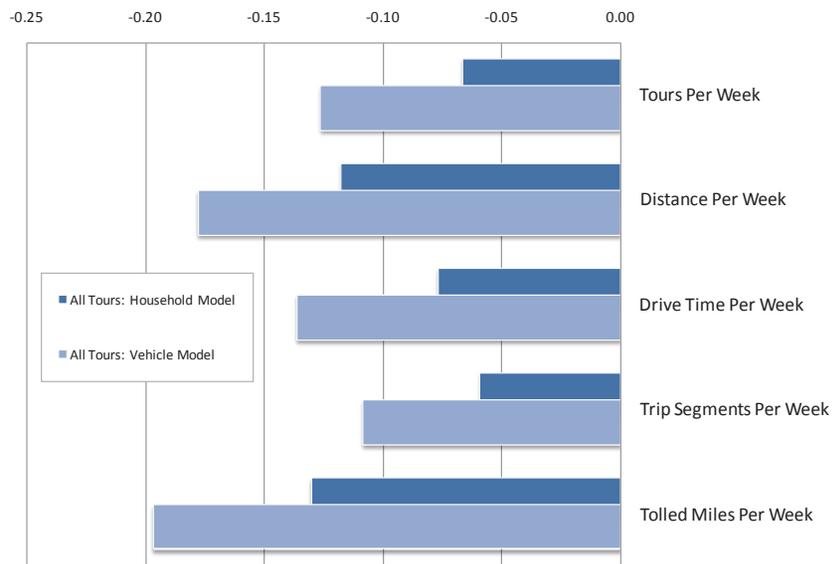
<sup>4</sup>The incremental change in vehicle operating cost in was calculated as the difference in the average gasoline price per gallon during week t of experimental period and the average price per gallon during the control period multiplied by 0.05 (the inverse of 20 miles per gallon) multiplied by the average control period tour length in miles.

of the GPS study as it is generally viewed as the decision making unit by economists and it forms the basis of observation in the GPS study. The Household models are based on the GPS data aggregated to the household level. All vehicle tours—regardless of driver—originating from or concluding at the household are aggregated by purpose (e.g. home-to-work) in the household tours. The debit accounts from which tolls were paid were set-up for households, not for individual drivers, thus decisions affecting the accounts were made at the household level.

Analysis was also conducted from the perspective of the individual vehicle, which may be regarded as an imperfect proxy for the individual driver—imperfect because residents of a household often share the use of one or more vehicles. Nevertheless, the vehicle perspective allows for examination of changes in driving behavior as it affects choices associated with driving the individual vehicle.<sup>5</sup> The distinction between the household and vehicle perspectives is subtle and is largely an issue of aggregation (i.e., household level data represents the aggregation of vehicle level data), but we were interested in testing the a priori assumption that the elasticity of driving behavior would be greater at the vehicle level than at the household level. That is, households would have greater ability to adjust their behavior in response to tolling by adjusting their use of individual vehicles than by adjusting their aggregate commuting behavior.<sup>6</sup>

The third perspective considered in the analysis was the workplace. The data generated in the analysis does not indicate definitively which tours originated or concluded at an actual place of work for the participants of the study. However, by screening the data through a number of filters (e.g. point-to-point vehicle tours that occurred on a routine schedule and remained at the location for a sufficient amount of time), we were able to isolate those tours that likely corresponded with a workplace. Nevertheless, some of the tours that we defined as workplace oriented were likely not.<sup>7</sup> For example, routine commutes by students to school may be defined as workplace tours in our analysis, as would routine tours by individuals to volunteer in a school, church, senior center, or other facility. From a practical perspective, these tours are similar enough to a workplace-oriented tour to be considered as such. Again the distinction between aggregating the GPS data at the household or workplace level may seem

**Exhibit A.3. Household and Vehicle Sensitivity to Toll Costs: All Tours**



academic, but we were interested in testing the a priori assumption that from the elasticity of driving behavior would be smaller at the workplace level than at either the household or vehicle level. That is, households may shift between vehicles and may choose to carpool in order to save on tolls, but they have less discretion regarding the decision to commute and the timing of the commute to their workplace.

Impact model results are presented below for all dependent variables except Tour Start Time Per Week and Tolls Paid Per Week. Tour start time analysis using logit model estimation is described later in the report as these models produce findings that are easier to interpret than the impact models that focus on the absolute value of the tour start time adjustments. And the explanation of tolls paid is likewise discussed independently since these models are distinct from the other measures of demand in that tolls paid is a measure of aggregate demand response to the experimental tolls. Exhibit A.3 above displays household and vehicle level demand elasticities for all tours, followed by figures displaying household, vehicle and workplace elasticities for home-to-work, work-to-home and home-to-home tours.

<sup>5</sup>Because the GPS data were collected at the vehicle level, it is the most disaggregate of the three perspectives.

<sup>6</sup>For example, members of a household could carpool, thus reducing the use of one or more vehicles while still engaging in their necessary commutes.

<sup>7</sup>Our screening procedures also likely left out workplace oriented commutes, such as those to workplaces that shift on a frequent basis (e.g. construction workers shifting between job sites or ending one job and beginning another).

When measured across all types of travel purposes, and all study participant households (or vehicles), the toll policy used in the study resulted in a number of important changes in aggregate travel demand. These included:

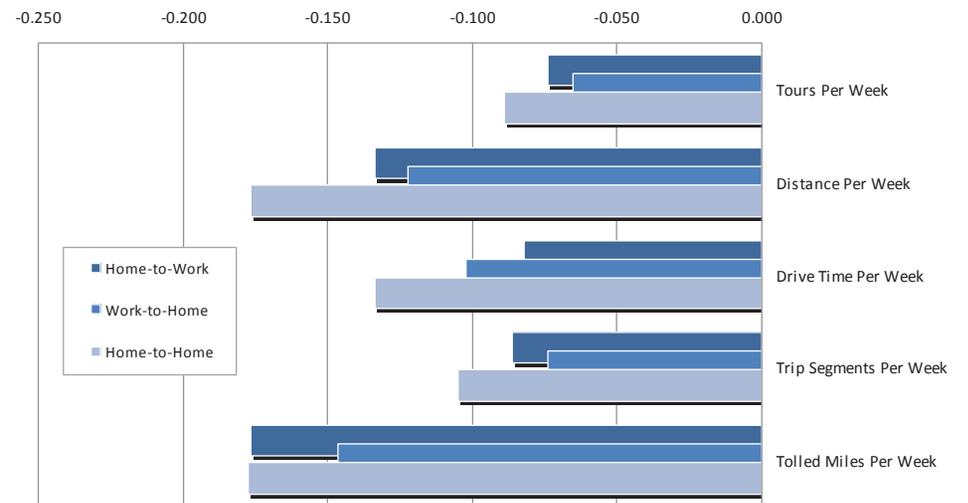
- 7% (and 13%) reduction in all vehicle tours (tours per week)
- 12% (and 18% reduction in vehicle miles traveled (miles per week)
- 8% (and 17%) reduction in tour drive time (minutes of driving per week)
- 6% (and 11%) reduction in tour segments (segments of tours per week)
- 13% (and 20%) reduction in miles driven on tolled roads (tolled miles per week)

The participating households altered the nature and amount of vehicle use in response to experimental tolls that increased the costs of travel but did not result in improved travel times. To demonstrate the full consequences of the variable toll policy the study needed to estimate a new demand and supply equilibrium.

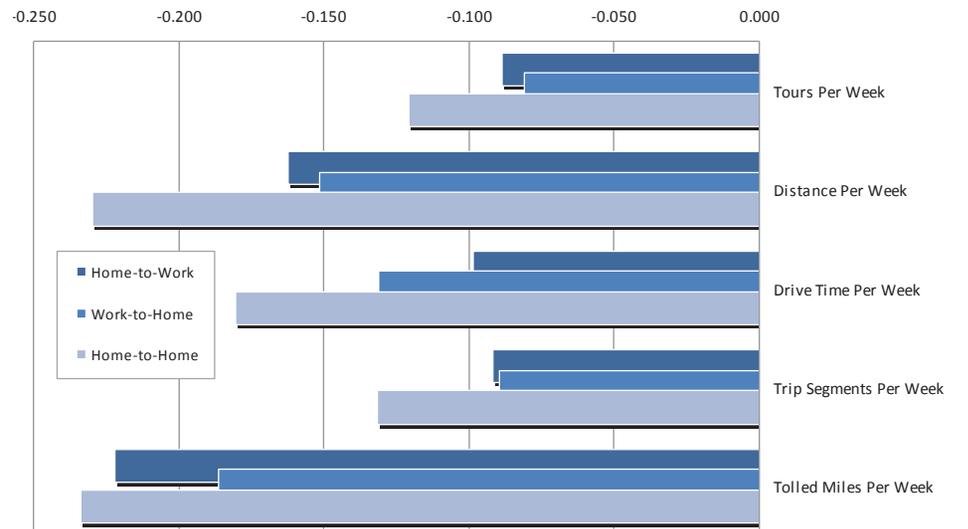
The specific effects on individual tour types (home-to-work, work-to-home, and home-to-home) were both higher and lower than these aggregate effects, as displayed in [Exhibit A.4](#) through [Exhibit A.6](#).

Analysis of the data revealed important changes in household driving patterns that could significantly reduce congestion if variable tolling were implemented within a regional road network. Many households made notable changes in their travel practices. Households that modified their travel did so in many different ways: taking fewer and shorter vehicle trips, choosing alternate routes and times of travel, or linking trips together to reduce vehicle use altogether. Some households altered their routine travel practices (such as how they moved between home and work); other households made changes when they could, in more irregular ways over the course of daily events. Some participants report that these changes have persisted beyond the end of the study. Other households appear to have had very limited opportunities, in the short-run, to avoid using high demand roads during peak travel times. On average, demand response measured by households is less pronounced than when measured by individual vehicles. As expected, households have the ability to integrate travel planning across vehicles or individual household members. Demand response is less pronounced as income increases, as demonstrated

**Exhibit A.4. Household Sensitivity to Toll Costs by Tour Purpose**

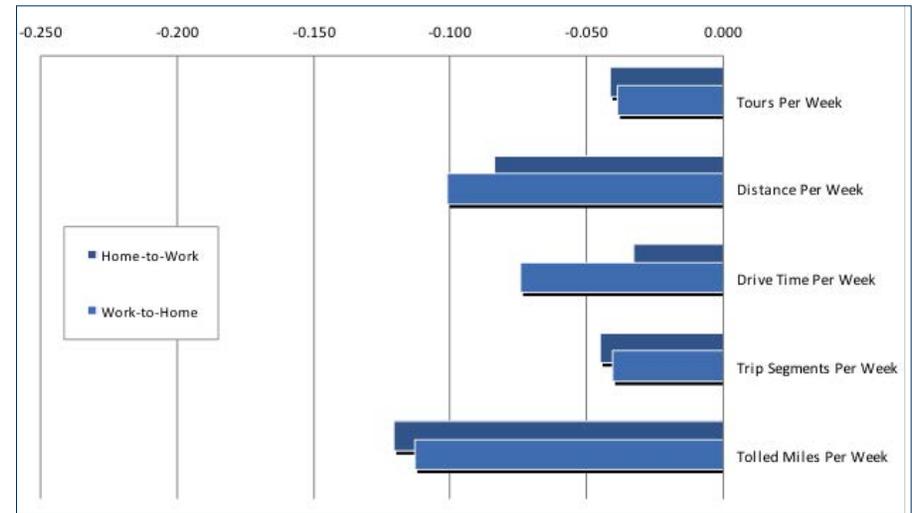


**Exhibit A.5. Vehicle Sensitivity to Toll Costs by Tour Purpose**



through an examination of the sign of the coefficients for income. And the workplace models that contain a measure of transit viability<sup>8</sup> matched to the specific origin and destination locations for work related tours demonstrates that a higher quality of the transit alternatives to driving is modestly associated with a larger price elasticity of demand for vehicle use. Exhibit A.7 displays the influence that the availability of quality transit options has upon the Home-to-Work tour toll elasticity of tours taken per week. Each study work tour was ranked for the quality of transit services available between home and work locations. The toll elasticity of tours for the Home-to-Work tour measured across all workplace locations was approximately -0.04. This value did not change notably over most of the distribution of measures of worker’s transit viability. For the workers with the best transit service options (above the 90th percentile) the tour response (effect on the number of vehicle tours per week) increased to as much as -0.16. Current transit service options appear to provide only a small degree of opportunity to avoid paying tolls in all but the most transit “friendly” of circumstances.

**Exhibit A.6. Workplace Sensitivity to Toll Costs by Tour Purpose**

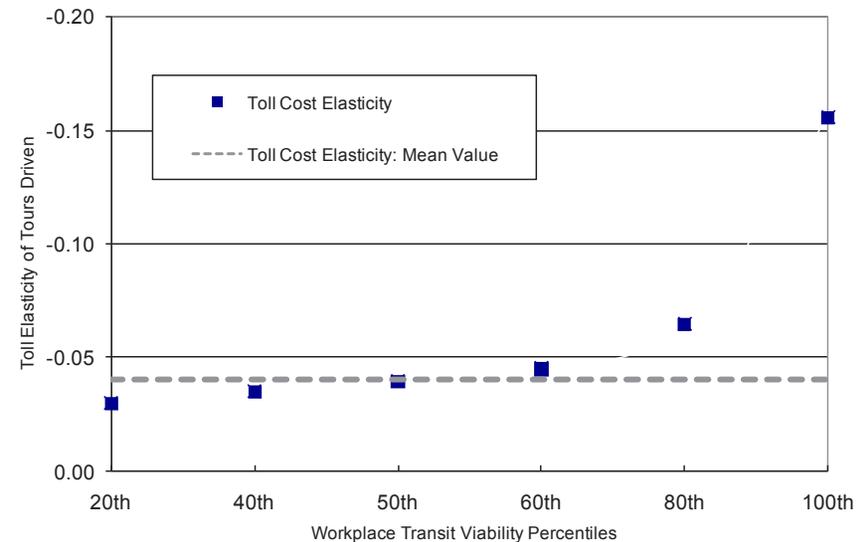


**TOUR START TIME RESPONSE**

In addition to the behavioral responses discussed above, study participants could also respond to tolling by moving the start time of their tour into a lower cost toll period. We considered three statistical modeling frameworks to examine the start-time response of study participants.

1. Ordinary Least Squares (OLS) model based on the absolute value difference in start time between the control and experimental period.
2. Ordered probit analysis to examine the probability that participants chose one of the three options between the control and experimental periods
  - a. Moved to a higher toll-cost period in experimental period
  - b. Remained in the same toll-cost period in the experimental period
  - c. Moved to a lower toll-cost period in the experimental period
3. Binomial logit analysis to examine the simpler question: what is the probability that a participant would move to a lower toll-cost period?

**Exhibit A.7. Influence of Transit Quality on Toll Elasticity of Home-to-Work Tours**



<sup>8</sup>Transit viability is measured as a ratio of transit generalized costs of travel and auto generalized costs of travel between each individual origin and destination zone pair. This ratio is then transformed into a scale factor between zero and one.

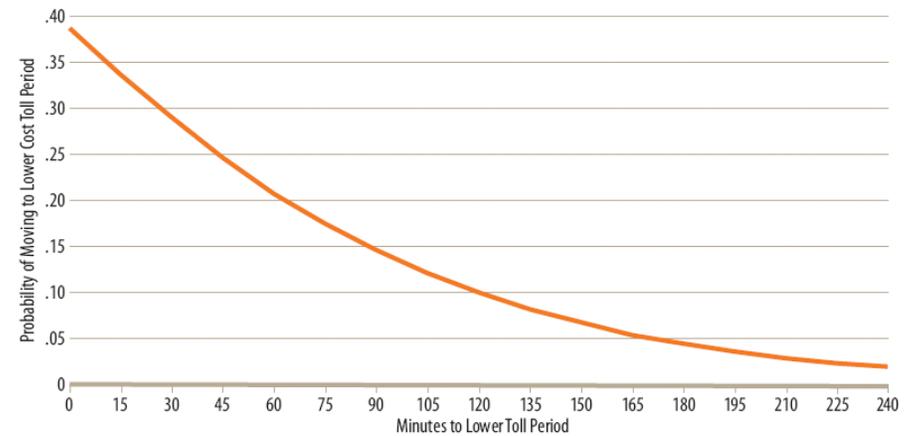
In the OLS modeling approach, we analyzed participant behavior in a manner similar to the analysis of the other behavioral responses. We compared the average weekly start time for each tour type in the experimental period to the corresponding average start time in the control period. The absolute value of the difference in the start time—in minutes—was regressed on the same explanatory variables considered in the other behavioral models. Although this was an intuitively appealing approach (i.e., we didn't care if commuters began their commute earlier or later, we only wanted to measure the absolute value of the difference in starting time), this approach had a critical shortcoming: the dependent variable is censored at zero because we measured the absolute value of difference in start time.<sup>9</sup>

The ordered probit modeling approach was considered because it allowed us to directly model the three possible ordered responses of the participants: moving to a higher toll-cost period, staying in the same toll-cost period, or moving to a lower toll-cost period. The results of these models were reasonable with respect to sign and significance of the coefficients, however the results have very limited practical use. For example, though we were able to statistically confirm the a priori assumption that the higher the “but for” toll faced by the participant, the more likely they are to move to a lower toll-cost period, the results of the ordered probit model do not allow for the development of behavioral elasticity estimates to apply outside of the model.

The binomial logit model was considered because of two key strengths. First, it provides a modeling framework to address the simpler and more relevant question “to what extent do drivers respond to tolls by changing the start time of their tour to a lower cost period?” This is the relevant economic question and one easily developed from the GPS data. Second, using the coefficients estimates from the logit regression model, it is a simple matter to estimate the probability that a driver will move to a lower toll-cost period given either the difference in toll cost between the two periods or the time (in minutes) to the nearest lower-cost toll period.

The probability of moving to a lower toll-cost as a function of the proximity to the nearest lower cost toll period (given the specific toll structure employed by the experiment) is displayed in [Exhibit A.8](#). If a study participant typically made a work trip (during the baseline/no-tolling part of

**Exhibit A.8. Home-to-Work Probability of Shifting to Lower Toll Period**



the project) at a point in the day that is within 15 minutes of a lower toll-cost time period, then there is a 40 percent probability that during the tolling part of the project, the trip was made during the lower toll-cost time of day. This probability dropped to 20 percent when the trip typically occurred within 60 minutes of the lower toll-cost time period, and was below 5 percent when the trip would have occurred within 180 minutes of a lower toll-cost time period. This is strong evidence of time shifting response to tolls when the departure delays necessary to avoid some increment of toll costs are small. A more finely tiered tolling structure (with shoulder tolls different from the peak and off-peak period) than the one used in the study would afford opportunities to finely tune the performance of major road facilities.

### ELASTICITY OF TOLLS PAID

In the context of a tolling experiment, the tolls actually paid are a behavioral outcome of the experiment. This behavioral dimension is of interest because it measures the ability of the participants to avoid the nominal, experimental toll treatment. In addition, the observed willingness of participants to travel slower paths to reduce toll exposure reveals that the tolls were at meaningful levels relative to the value of time. Going into the experiment, tolls were set using value of time information from PSRC's regional travel model. Had there been no response of tolls paid with

<sup>9</sup>OLS regression fails to account for the (zero) limit in the data. An alternative approach, to Tobit model, was considered. The Tobit regression model (see Green (1993) for more information on Tobit regression) accounts for the censoring problem inherent in some economic data, but was deemed to not be a practical alternative for these data.

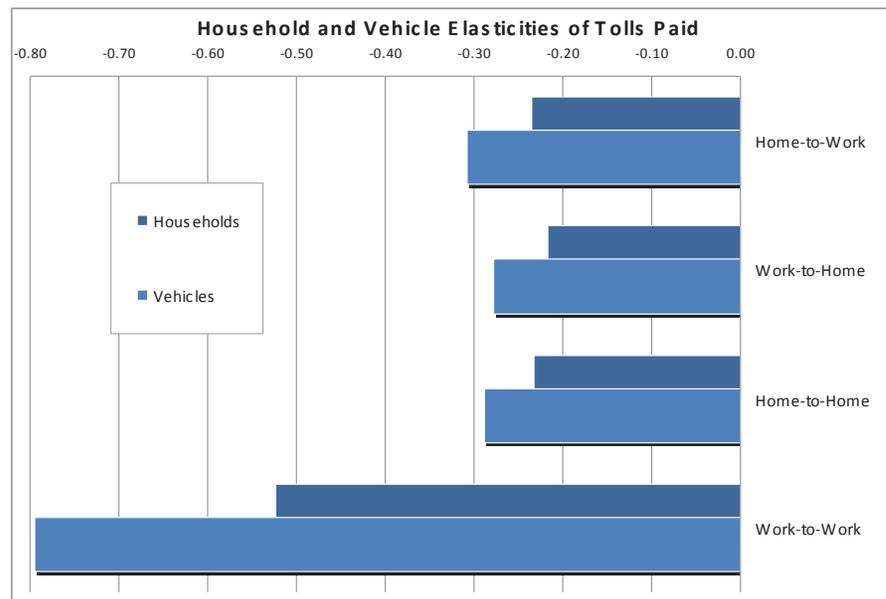
regards to base case experimental toll levels, then the meaningfulness of the experimental toll levels might have been called into question. The finding of a high elasticity of tolls paid with respect to the experimental toll treatment confirms that behavior is plastic with respect to toll levels.

Interpretation of the measured elasticity of tolls paid with respect to the experimental tolls or generalized cost has to be done carefully. The measured elasticity of tolls paid is quite high. There is a natural tendency to interpret this as meaning that tolls as a new increment to generalized costs of travel are easily, and significantly, avoided. However, it must be recalled that the experimental toll that constitutes the right hand side variable of the impact regressions is the toll per tour that would be paid under the touring conditions observed prior to the experiment. The left hand side variable, however, is the weekly total quantity of tolls paid--not the toll paid per tour. The latter can be computed, of course, because the reaction of the number of weekly tours also is measured. However, the reported elasticity is between a per tour price, and a per week quantity. In such a setting, the elasticity correctly renders the response, but by no means are participants able to avoid a high percentage of the toll charged per tour.

From the perspective of a regional implementation of toll policy, the elasticities of toll revenue with respect to statutory toll levels also is of interest. From a static perspective, it is tempting to estimate toll revenues by applying the statutory toll levels to existing trip or VMT quantities. What the high elasticities measured

in the experiment reveal is that nominal or static toll revenues are higher than those that actually will be revealed in toll paying behavior. This is an obvious point, of course, since we expect behavior to respond to tolls. However, policy makers can use these elasticities to quickly determine the revenue potential of a particular toll policy. That is, use of these measures permits a short-hand means of rendering the dynamic revenue implications of a toll without having to articulate the full complexity of the path through which tolls paid adjusts to a nominal toll change. Elasticities of tolls paid (by tour purpose) for both households and vehicles are displayed in [Exhibit A.9](#).

**Exhibit A.9. Toll Cost Elasticity of Tolls Paid**



## APPENDIX BI-B: PRIVACY AND ROAD USE FEES

To better assess the issues of privacy policy and network road fees it is essential to try to answer a few basic questions. First, are there clear established rights to privacy? Second, what specific concerns are privacy advocates likely to have with a GPS-based network charging system? Third, what specific information about users is likely to be collected and stored by such a system? Fourth, what standards for privacy protection might be helpful in the design of toll system privacy protections? All these questions are distinct from questions regarding data security. It is assumed that tolling data can be made reasonably secure, but that privacy concerns may still persist.

While certain Constitutional provisions have come to be referred to as rights of privacy, there is no clarity as to what the right to privacy is, as granted under the U.S. Constitution and Bill of Rights. And case law concerning what is private and what is not private is often fraught with ambiguity. The First Amendment protects speech and religious belief and can be construed to be a protection of the privacy of thoughts and beliefs. The Third Amendment protects against the quartering of soldiers during war time and is seen as a protection of the privacy of the home. The Fourth Amendment protects against unreasonable searches and seizures, and may be seen as a protection of the privacy of a person and their possessions.

In general, however, what one does in a public space, such as a public road right-of-way is not

necessarily considered to be private. There is no clear expectation of privacy while one uses public rights-of-ways. Data stored and collected about individual's use of roads may, depending upon local laws, be protected in some manner as private information. While establishing privacy as a right in the context of questions of road tolling may be challenging; often there is a general public sentiment that such information is, in fact, private information and should not be used without the consent of the individual users.

In 1995 the European Parliament passed Directive 95/46/EC<sup>10</sup>, on the protection of individuals with regard to the processing of personal data and on the free movement of such data. This Directive is an example of specific direction on how information collected by governments about private individuals should be managed.

The main provisions of the Directive include Article 6, stating that Member States shall provide that personal data must be:

- (a) processed fairly and lawfully;
- (b) collected for specified, explicit and legitimate purposes and not further processed in a way incompatible with those purposes;
- (c) adequate, relevant and not excessive in relation to the purposes for which they are collected and/or further processed;
- (d) accurate and, where necessary, kept up to date;
- (e) kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the

data were collected or for which they are further processed.

Article 7 lays out criteria for making data processing legitimate by indicating that Member States shall provide that personal data may be processed only if:

- (a) the data subject has unambiguously given his consent; or
- (b) processing is necessary for the performance of a contract to which the data subject is party or in order to take steps at the request of the data subject prior to entering into a contract; or
- (c) processing is necessary for compliance with a legal obligation to which the controller is subject; or
- (d) processing is necessary in order to protect the vital interests of the data subject; or
- (e) processing is necessary for the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller or in a third party to whom the data are disclosed; or
- (f) processing is necessary for the purposes of the legitimate interests pursued by the controller or by the third party or parties to whom the data are disclosed, except where such interests are overridden by the interests for fundamental rights and freedoms of the data subject which require protection under Article 1 (1).

The Directive also covers the subject's rights of access to the data, rights of notification about data processing and rights to formally object to data processing, how data can get transferred

<sup>10</sup>[http://ec.europa.eu/justice\\_home/fsj/privacy/index\\_en.htm](http://ec.europa.eu/justice_home/fsj/privacy/index_en.htm)

to other parties, judicial remedies, liabilities and sanctions. Member States are required to “bring into force the laws, regulations and administrative provisions necessary to comply with this Directive”.

Such an approach renders less ambiguous questions about whether any given governmental program complies with basic privacy protections. In the case of a road tolling system, it is feasible to design systems, practices and safeguards that will meet international standards, thus moving any debate about privacy from the abstract to the particular.

If one was to take the European case one step further, this Directive is implemented in the specific case of the Netherlands by means of the Personal Data Protection Act.<sup>11</sup> This is a useful example because the Dutch government is planning on implementing a nation-wide road tolling system based on GPS technology. As a result the Dutch government will have to explicitly consider how such a tolling system will comply with national law protecting personal information.

## **PRIVACY CONCERNS THAT MIGHT BE RAISED BY A NETWORK TOLLING SYSTEM**

### **Illegal or unauthorized use of personal data**

Even as more commerce and personal transactions take place through digital means, the illegal possession and use of personal data is rare. But when a breach in corporate or institutional security does occur it can have sizable consequences for innocent parties. Most often, such cases, which may receive much publicity, involve the illegal compromise

of an institutions computer systems containing account holder information, possibly including records allowing access to financial accounts. However, data security and encryption technology has become so advanced that an actual breach of a computer system is extremely rare. And situations where account holder files have been access mostly involve situations where an unsecured storage medium has been stolen (such as data temporarily stored on an employees laptop), or are the result of users directly and unknowingly providing access to account information (account information and passwords stored on individuals unsecured home computer systems or account holders responding to requests to provide account information to someone posing as a legitimate account manager). Still, technical all systems have vulnerabilities, and a road tolling system with a large database of account holder information could never be 100% immune to breaches in security.

One suggested way to address data security for road pricing applications is to limit the detail of information a road tolling system would contain in its central office. This is the so-called Thick-Client model discussed elsewhere. Since information about specific road use is never sent to the central office two important points of data vulnerability become less critical; data transmission and central data storage. However, it is important to realize that detailed data will still be stored (at least temporarily) within the vehicle itself. The user end of the data chain is possibly the point of greatest security risk, as examples of breaches in the security of financial accounts suggests.

### **Official use of data for other than intended purposes**

Another concern regarding the storage of detailed information about people's physical movements within their vehicles involves the availability of that information to “official” entities to support purposes other than those originally intended by the road tolling program. Law enforcement, for example, might be keen to make use of information about the movements of “parties of interest”. Lawyers involved in litigation might find use for similar information in particular cases. In the clearest cases, most people would have no quarrel with the selective and responsible use of this kind of data when employed to catch a dangerous criminal. It is the many hypothetical and more ambiguous circumstances that engender a healthy skepticism on the part of the average person. Road pricing would not be the first situation where such complex questions about privacy protections are raised. Legal and institutional structures can be put into place to minimize the opportunities for unintended use of personal data. The Directive of the European Parliament discussed above is an example of such a legal framework. Still, the process of sorting all this out can often be a messy business involving courts and legislative refinements taking place over a number of years. The approach that focuses on legal and institutional protections is one that must, by necessity in the short-run, say: trust us; we will be responsible in keeping your personal information secure. The point here is that the notion of trust is essential, and that institutional protections often involve what has become referred to as a “trusted third-party”

<sup>11</sup><http://english.justitie.nl/themes/personal%2Ddata/>

(an institution that has controls over the processes but has not direct interest in the control of the data itself).

### **Information Collected and Stored by a Network Tolling System**

Tolling a network of road facilities, such as was done during the Traffic Choices Study involves collecting detailed road use information for any applicable vehicles and associating that information with accountholders that are responsible for payment. In the case of a tolling system that relies upon global positioning system technology, the road use information that is collected may be as detailed as a trail of precise waypoints and time stamps at one second intervals. GPS tolling devices can calculate and store this level of detail about a vehicle's location for an extended period of time. In the case of the Traffic Choices Study, the tolling meters could store up to approximately two weeks of positioning data before running out of allocated memory. When this level of detailed vehicle use data is associated with user account information, in a tolling back office, it is possible to determine the precise movements of vehicles and individuals.

Thus a principal aspect of privacy has very little to do with the data that is stored within the vehicle on the tolling meter, or on-board unit, but rather what data actually leaves the vehicle to be stored as part of the back office operations (facility use determination, violation processing, and billing) of the toll system. In this regard, a GPS toll system can be operated in a manner that either stores detailed road use information

in the back office, or in a manner that stores only summary road use information that abstracts from the use of specific roadway facilities.

### **Thick or Thin Client**

The two operating approaches have come to be reference according to the functionality of the in-vehicle tolling meter, as a thin or thick client. The thin client is an OBU (in-vehicle toll meter) concept where all raw data is transferred to the back office. In the back office, the data is processed and the road segments are recognized and matched with the toll rate table. This means that all information relevant for tolling is calculated in the back office. All information is retained at appropriate detail to meet evidentiary standards and for a period sufficient to cover dispute opportunities

In the thick client approach, the tolling process takes place in the OBU; the algorithm for the road section recognition is integrated in the OBU. After the road section is recognized, the toll rate is processed in the OBU according to the type of the road, time period, and vehicle class. The sections and driven distances can be sent to the back office in aggregate together with calculated road usage fee. Specific road use details are never stored in the toll system back office. If the fee is calculated in the OBU it is also possible to integrate a card slot (for usage of cash cards) into the OBU in order to achieve maximum privacy for the participants.

However a toll system is operated, it is important to remember that there is no absolute technical safeguard for personal information when road usage must be verified and processed for

payment. Even if detailed data is stored only in the participant's vehicle, it is vulnerable to discovery and misuse. But reasonable safeguards are an essential part of any business or government process that makes use of, or has access to, private information.

### **Toll System Privacy Protections**

Addressing privacy concerns around toll system implementation can take many forms; the safeguards can be technical, institutional or legal but ultimately need to be a total package that are mutually supporting. Technical approaches might include thin versus thick client models, the use of anonymous proxies, and the purging or sanitization of data. Institutional approaches might limit the scope of information available to any single institution; separating personal data from road use data. But any approach will require a legal framework that ensures that privacy is adequately addressed with technology and institutional structures.

[Exhibit B.1](#) (on the following page) itemizes some very general privacy protection principles and how these principles might be addressed in toll system design.

This report does not systematically inventory or assess approaches to addressing the dimensions of privacy that arise as a result of system level road charging. The fee system could result in significant concerns about the potential use of data regarding the location and movement of individuals. Authorities that are considering actual implementation of road charging through vehicle positioning, such as some in Europe, are able to take a much more

**Exhibit B.1 Principles and Measures to Protect Privacy**

Principles	Measures/Remarks
Capture only data necessary for the defined purpose	Define which data are captured for what purpose, and let the public know what data are collected and why.
Don't keep data longer than necessary	Ensure that obsolete data will be permanently deleted.
Distribute data only when necessary	Field components capable of processing data should perform the data reduction autonomously.
Maintain anonymity as far as possible	If the system is used for other purposes than road pricing (e.g. traffic data monitoring) de-personalization is possible and should be done.
Make sure data can not be accessed by unauthorized individuals	Encryption of data-flow at insecure communication channels. Hierarchical access rights for individuals only to data of relevance within a secured area.  Payment via a web based application will be done over https: protocol, already common in other payment processes.
Mitigate impact of intrusion	System redundancy and encapsulation of critical processes are not only measures to maintain system availability but will also minimize the impact of intrusion. The external system interfaces are reduced to the absolutely needed and secured by state of the art hardware and software system components.
Transparency	Consultation with the local people about the capturing zone of the cameras so that they do not intrude into private rooms, restaurants, businesses, etc.

considered approach to evaluating privacy concerns and designing practical solutions. Specific toll system proposals will require specific solutions; solutions that could not be designed into a field study such as the Traffic Choices study. However, Traffic Choices study participants did have a unique experience involving vehicle positioning tolling technology, and as such can provide some insights into the topic of privacy. A survey of participating households conducted at the end of the study asked for any additional comments households wished to advance regarding any aspect of the study. Such an open ended question resists systematic analysis but provides some general sense of what was on the minds of the participants after having spent considerable time involved in a research experiment. Concerns about privacy featured in the responses, but did not dominate. This can be seen in the [Exhibit B.2](#) on the following page.

A specific question regarding privacy was also asked of the Traffic Choices Study participants during a “startup” and an “exit” survey.

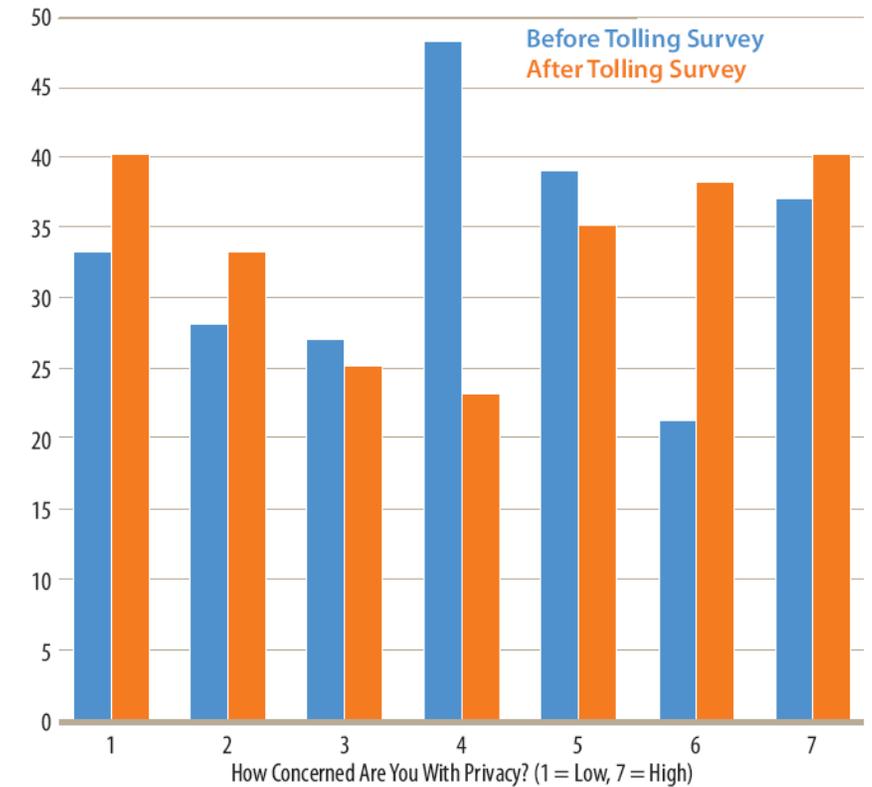
[Exhibit B.3](#) (also on the following page) presents the results from a survey question related to privacy concerns regarding tolling. Experience with the road tolling experiment appears to have helped individuals clarify their own views on the topic of privacy. Before the experiment a fair number of participants were ambivalent about the issue of privacy. After the project was complete, participants had become less ambivalent and were (as a group) both more and less concerned about privacy. This result points to a possible benefit of more refined research with a focus on addressing specific privacy aspects of the toll systems that remain a concern for individuals who have previously gained some tangible experience with the tolling technology.

**Exhibit B.2. Household Survey – General Comment Categories**

Comment Topics	Number
Lack of flexibility to respond to tolls	32
Indicating some significant change in travel behavior	17
Found road use information useful/interesting	11
Roads should be free/objection to tolls	8
Expressing a need for better alternative modes of travel	7
Indicating support for tolling	7
Importance of focusing revenues on transportation	4
Concern about traffic diversion	3
Expressing the need for more roads	1
Preference for gas tax	2
Compliment about some aspect of the project	9
Complaint about some aspect of the project	5
Complaint about the tolling device (OBU)	3
Concern about privacy	7
Concern about fairness	5
Regarding some aspect of study design	7
Regarding study toll rates/rate policy	5
Misc. comment	12
<b>Total comments</b>	<b>145</b>
<b>Percent of respondents that offered comments</b>	<b>53%</b>

**Exhibit B.3. Household Survey – Privacy Concerns**

*How concerned would you be about the privacy implications of a toll system that collects specific road use information for individual vehicles?*



## APPENDIX BI-C: TRAFFIC CHOICES SYSTEM REQUIREMENTS

The project team determined system requirements based on the study's primary objective: to collect information about drivers' use of the road system that would permit detailed assessment of how they made different choices when faced with tolls. The requirements for this experiment differed in important ways from the requirements that would support the implementation of a toll system as a revenue operation: they did not include payment processing and enforcement elements. In most other respects, the core elements of the "experimental" toll system mirrored those necessary for full revenue operations. This connection to practice was reinforced by the fact that the experimental toll system was developed by firms directly involved in toll system design.

### ON-BOARD UNIT (OBU)

This device within a participant's vehicle showed the driver the current charging rate (toll) for the facility (road) she was driving on, and recorded the vehicle location using GPS technology. The specifications for the ideal OBU for the experiment:

- Capable of storing road map files, road price tables, and collected waypoint data sufficient to permit a toll calculation within the OBU itself. The project team recognized that we might have to settle for an alternate (less desirable) solution with route identification and toll calculation occurring at central data server.
- Capable of wireless communication with the Central Management System (CMS) that occurs at an interval necessary to transmit toll calculations and update account information.
- Permit successful map matching all location points necessary to correctly managing billing processes, and should be designed such that it works reliably under all environmental conditions.
- Readily mountable within the vehicle, be able to be removed without leaving any permanent damage and should incorporate a display of the current charge rate that can be safely read by the driver while driving.
- Tamper resistant and protected from being detached from the vehicle without authorization.

### TOLL CALCULATION SYSTEM (TCS)

The Toll Calculation System (TCS) needed to match the position of the vehicle (from the location data collected by the OBU) with road information and assign a toll value that would be displayed in the vehicle and billed to the account. An ideal TCS would be embedded in the OBU and would allow toll calculations to occur without a transfer of data outside of the vehicle, and would include a map with enough precision to accurately assign prices. The TCS would include a function that allows common routes to be named and priced by name. If the TCS could not provide accurate toll information from within the vehicle, an alternate approach would be to transfer vehicle geo-coordinates to the Central Management System for map matching and toll calculation.

### CENTRAL MANAGEMENT SYSTEM (CMS)

The Central Management System needed to collect, store, and organize account data. If the OBU system would not identify routes and calculate tolls internally, these data would need to be transmitted to the CMS and back to the OBU using a local, commercially provided wireless network. The CMS would need to be secure, have redundancy and be capable of backing up data/reports, and be able to log all data received and transmitted.

### ENDOWMENT ACCOUNT MANAGEMENT SYSTEM (EAMS)

Participants were to receive an electronic endowment account based on their travel patterns before tolling was implemented. The Endowment Account Management System (EAMS) would manage those accounts. As participants drove on priced roadways the tolls would be debited from the account balance. The EAMS would communicate with the CMS account data and handle all the billing functions. The EAMS would provide regular (monthly) customer billing statements to experimental participants via mail or internet. The EAMS would also need the capability to reconcile accounts upon identification of errors and the ability to confirm account resolution to the PSRC and the experiment participant. The EAMS would provides web-based customer access to endowment accounts with system updates made on at least a daily basis.

**ROAD NETWORK AND DATA RESOLUTION**

The toll system would need to guarantee functionality of all systems and assure data integrity. The system would have to accommodate the complexity of participant trip characteristics, faithfully simulate efficient system-wide tolling to the participant, and measure pricing response. The system would incorporate a variety of links that are priced at different levels. For the experiment to accurately simulate ubiquitous, efficient pricing, the OBU would, at a minimum, charge tolls and report (to the driver and to the data center) when the driver travels through one of these links.

Exhibit C.1 displays the number of roadway links in the PSRC travel demand model that carry volume to capacity ratios of various magnitudes. Variable roadway tolling might be expected to apply to links carrying higher ratios of volume to capacity.

The project team looked to see what would happen if it set the volume-to-capacity threshold at 0.6. It resulted in selecting approximately 2,100 roadway links in the AM peak and 3,800 links in the PM peak as likely candidates for tolling. Budgetary constraints were again important. Establishing tolling on fewer links would make the experiment less like a real, efficient pricing structure. The team decided that the system should price at least 4,500 (i.e., 1,500 + 3,000) and up to 5,900 (i.e., 2,100 + 3,800) links.

For experimental purposes it was also important to measure how drivers use non-priced links. Ideally, the time of day, distance, speed, and path of trips on non-priced links would be captured by the OBU at a similar level of detail as priced links, but simplification of these data has less impact on the overall experiment design. Collected trip data for all links would include trip-level and vehicle-miles-traveled data sorted by vehicle and time period, departure times, trip lengths and paths (where paths are different roads, but not different lanes of the same road), and origins and destinations.

**Exhibit C.1. Candidate Links for Tolling**

V/C Ratio	AM Peak		PM Peak	
	Links	Link Share	Links	Link Share
0.6	633	3.8%	858	5.2%
0.7	441	2.7%	795	4.8%
0.8	360	2.2%	699	4.2%
0.9	253	1.5%	523	3.2%
1	159	1.0%	276	1.7%
1.1	110	0.7%	228	1.4%
1.2	59	0.4%	169	1.0%
1.3	27	0.2%	114	0.7%
1.4	34	0.2%	44	0.3%
1.5	20	0.1%	49	0.3%
Links V/C > 0.6	2,096	12.7%	3,755	22.8%
All Links	16,500	100.0%	16,500	100.0%

## APPENDIX BI-D: TRAFFIC CHOICES BACK OFFICE DATA MANAGEMENT FUNCTIONS

### GENERAL BACK OFFICE (DATA MANAGEMENT)

Traffic Choices Study used a pre-existing, integrated set of toll system applications developed by Siemens in Austria. Siemens designed the system for full-scale deployment and adapted it for this project. Siemens, through a local contractor, installed nearly 500 OBUs in participant vehicles. The OBUs recorded and stored the vehicle's position on links (with longitude and latitude values with GPS timestamp). The OBUs transmitted this data at least once per day to a Central Management System, which processed and stored this data in a database (which was also accessible through a web interface). Overall, the system provided the following functions:

#### Data management and setup

- Web Account administration
- Participant administration
- Vehicle administration
- OBU administration
- Tariff administration
- Association of OBUs with vehicles and participant accounts

#### Operation

- Toll link recognition and tariff selection
- OBU toll preview
- Location stamp recording
- Invoice generation
- Trouble ticket handling

#### System Maintenance

- Tariff updates
- Geo-data updates
- Parameter updates
- Software updates
- Status and error logging

In summary, the main components of the back-office system were:

- On-Board Units (OBUs): collected GPS position data and recognized toll road links. When a previously defined amount of data had been collected, or a time limit was reached, the OBU connected via a GPRS Internet connection to the Communication Server and sent the recorded data.
- Communication Server (COS): permanently connected to the Internet, it resolved incoming OBU messages, converted them and forwarded the data to the Central System. Any data exchange with the OBU was executed via the COS.
- Central Management System (CMS): consisted of two parts: an Application/ Web server and a Database Server. The Application/Web Server received the data

from the COS and stored it in the Database Server. The Web Server provided restricted access to the stored data via the Internet, allowing participants as well as administrators or service personnel to view or modify it. COS, CES and other IT components together formed the Central Management System.

### DATA COMMUNICATION

The study contracted for local wireless telephone and data communication services to allow communication between the OBU and the CMS. The wireless service provider issued SIM chipsets for each OBU used in the project. [Exhibit D.1](#) (on the following page) illustrates the system.

The OBUs were not permanently connected to the COS, but transmitted their collected data at least once a day. OBU and COS communicated with each other using a request/response principle. The OBU sent a request to the COS. The COS evaluated the request and sent a response, including any information about tolls or other factors. Normally, the COS did not initiate the communication. All devices communicated using HTTP to make sure software component usage (web server) was standard throughout the experiment and for scalability. The devices communicated more detailed information using a higher level protocol as a payload of the HTTP protocol.

The COS had a permanent connection to the CMS and created a gateway for incoming data, handling up to 500 connections at any given time. Persistent Message Queues (MQ) allowed for communication between COS and CES, and

each side could initiate communication. The communication was asynchronous; therefore there was no real-time confirmation of receipt of messages.

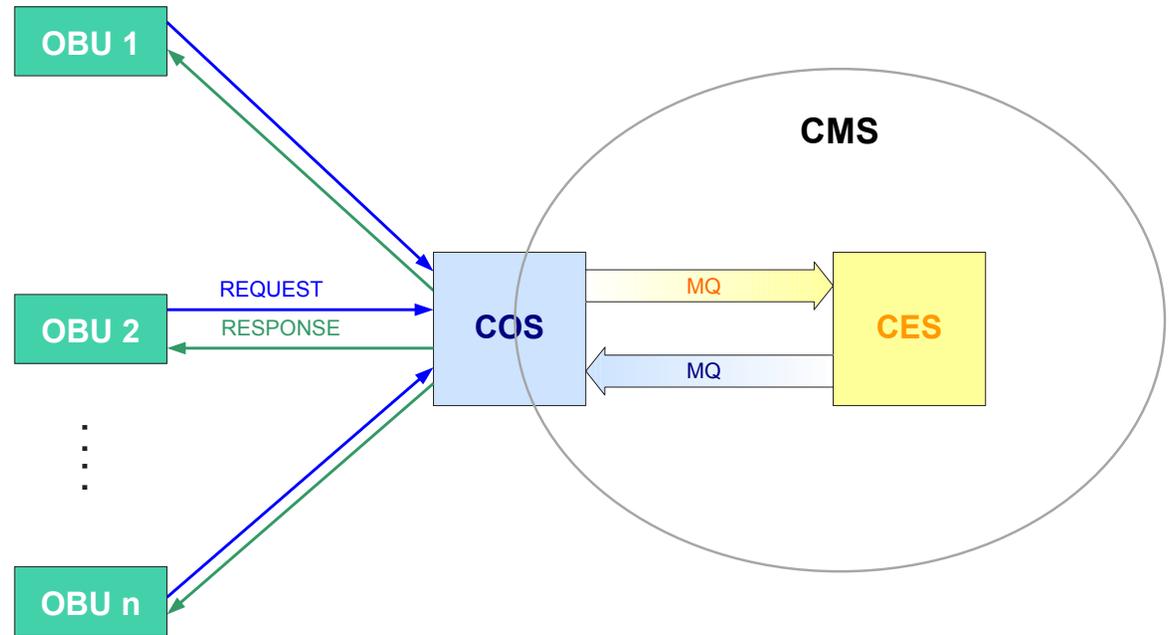
Wireless communication allowed OBU components to be updated, including: tariff data, parameters, firmware code, and geo-data. For each of these components the OBU maintained a current (active) version and stored a future (awaiting activation) version. Updates could only occur to the future version. For administration and distribution purposes, the time between initiation of an update and activation time needed to be at least 5 days. Each version contains an activation timestamp. When the OBU reached the activation timestamp of the future version, it activated this future version. If the update process in the OBU fails, the OBU is able to switch back to the previous version.

The OBU software was capable of full and delta updates. Tariff and parameter data were done as full updates; firmware and geo-data were normally done as delta updates. After generating the update, an external update generator tool (patch for delta updates and compression) created a component update package that the web interface transferred to the CES and to the OBUs via the COS.

The update process had the following steps:

1. External tools (geo-data, firmware, parameters) or the CES generated the update files
2. The external update generator tool produced the component update package

**Exhibit D.1. Communications between System Components**



3. The CES uploaded the component update package files
4. The web interface allowed for initiation and activation of updates
5. The CES transmitted the component update package file(s) to the COS upon initiation
6. The COS stored the version information and the component update package file
7. As soon as an OBU connected to the COS, the OBU sent its current component versions
8. The COS compared the versions and - if necessary - notified the OBU about an existing newer version

9. The OBU requested the new component version
10. The COS sent the requested component update package file
11. On each following reboot, the OBU checked if any update needed to be activated

**TARIFF MODEL**

The team used the PSRC’s model to estimate VMT-weighted average toll rates that would approximate the full, social costs of travel on different roads at different times of day. The project team based the range of tariff structures and toll schedule options on composite

measures of facility use. Each tariff structure considered types of variation, including travel direction, proximity to the urban core areas, and differentiation by time of day. The team considered the pros and cons of these options, weighing the statistical analysis advantages of complexity against the need for participants to have a simple, understandable toll structure.

Congestion varies across time and space within the road network, and ways that drivers respond to congestion-based charges include taking different roads in the network. Thus, any experiment attempting to understand the behavioral implications of efficient road tolling needs to be able to levy tolls on most major components of a region's road network: major surface roads and highways. Tolls must adjust depending on the facility, facility class, and time of day. Identifying the specific road network to which tolls, or charges, may be applied is a critical preliminary step in creating a successful tolling system.

### **BASE MAP**

A road tolling system that uses the Global Positioning System to match vehicles with the roads they use must also make use of a highly accurate digital map of the underlying road network. A vehicle's position in space and time can be determined with the use of GPS radio receiver technology to some reasonable degree of accuracy. But this position must be superimposed on a road map, or a set of spatial coordinates and attributes that represent actual road network characteristics. This digital road map is connected to the rules for setting toll levels, which are formulated within a toll (tariff)

model database. These connections between maps and tariff models are the information used by either the back office or the OBU to correctly charge drivers for their road use.

Many digital map files of the U.S. road networks are commercially available for use in such a road tolling system, although they vary in accuracy and network detail. Digital map accuracy is a function of how closely information in the digital map database approximates the actual road geometry. The Traffic Choices Study required a detailed digital base map that was sufficiently accurate to match drivers and roads with effectively no match errors. Accuracy is a function of several things, including the ability of the GPS device to correctly resolve its location, the accuracy of the base map of the road network, and the map matching approach employed by the positioning/tolling device, as well as sources of unknown error.

Base map requirements also depended on the methods for linking data about a vehicle's location with that map base. The Siemens tolling OBU matches GPS derived coordinates with the digital road map in the following manner. Any given road segment (say a portion of a road between any points of access and egress) is characterized by sets of spatial coordinates (latitude and longitude). One set of coordinates identifies the entry point of the road segment, while another set of coordinates identifies some other point on the road segment, downstream of the entry location in the direction of traffic flow (see [Exhibit D.2](#) on the following page). Each set of coordinates also has an associated radius measure that defines a circle around that point location. This circle is a zone within which GPS

returns (the vehicle location at a given point in time determined by the GPS signal receiving device) are "captured" and associated with that defined point in the road segment. The radius is sized to accommodate the extent of road geometry (multiple lanes), digital map error, and GPS signal error.

The OBU records drivers' use of toll roads by logging the GPS return every second that a vehicle equipped with an OBU traversed a road segment included in the toll network. This resulted in a trail of vehicle location points. The system matched the vehicle location with the toll charge by correctly associating the GPS return with that segment's entry and control location coordinates, as shown in [Exhibit D.3](#) on the following page. Other logic checks were supported by the system, such as consistency of direction of travel.

The PSRC possessed a digital road file of sufficient scale and accuracy to be used as part of the tolling system, although it required some modifications as described in detail in [Appendix B1-E](#).

Exhibit D.2. Example Road Segment

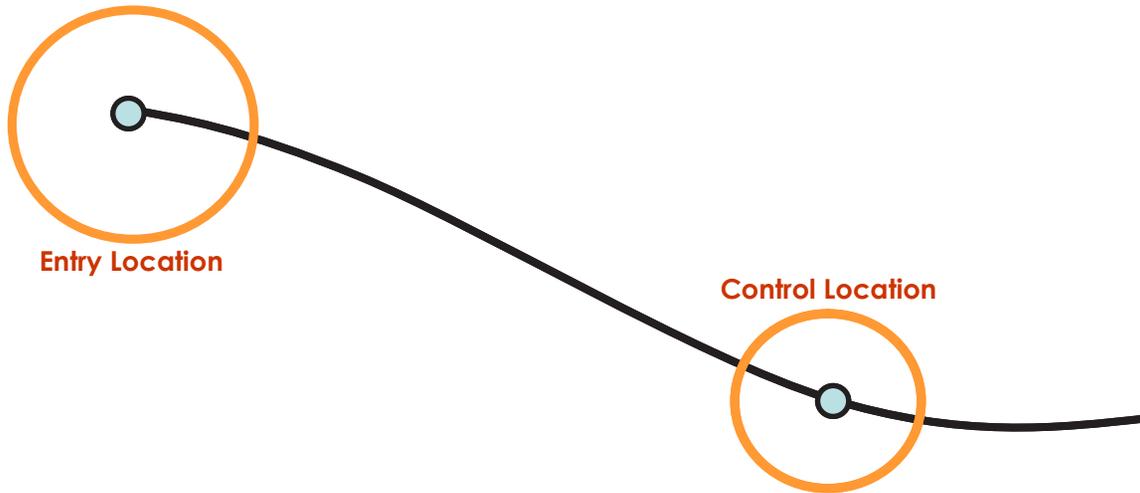
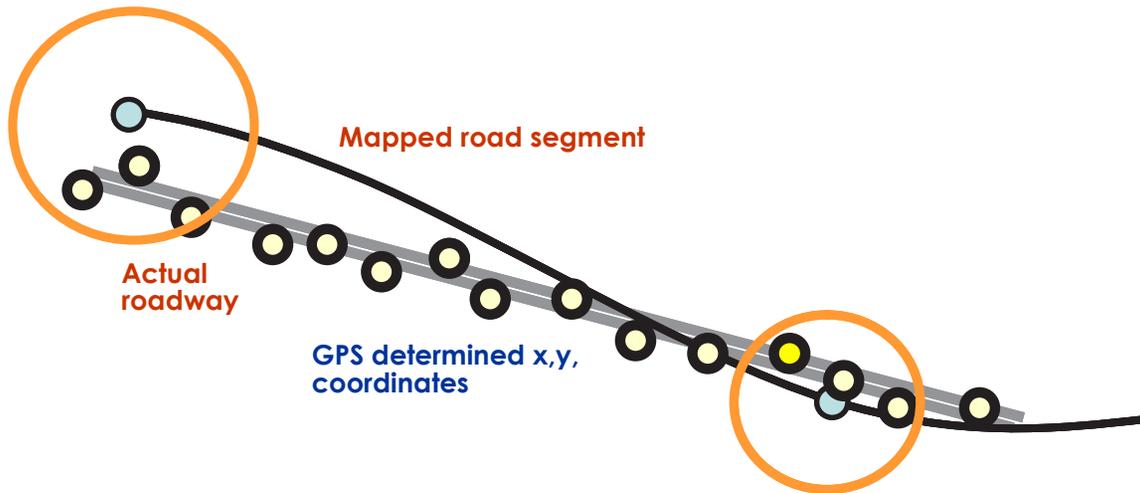


Exhibit D.3. Map Matching Concept



## APPENDIX BI-E: SAMPLE DESIGN FOR THE TRAFFIC CHOICES STUDY

Pilot projects that aim to understand consumer behavior must also adhere to scientific standards that allow for useful analysis to be performed at the conclusion of the study operation. Sample size is a key issue for any experiment. The sample for a study of road users should be grouped by households, as many households have multiple vehicles. A large sample is always preferred (everything else being equal) to a smaller sample. As a practical matter, however, the advantages of sample size must be balanced against the disadvantages of measurement error if sample size is gained by using a primitive measurement technology that introduces measurement error:

- Statistical precision (generally) only goes up with the square root of the sample size; hence, doubling the sample improves test precision by only 40%.
- Higher variance in measurement, in contrast, degrades precision in direct proportion to the standard error of the measurement distribution; hence, doubling measurement error halves statistical precision.

Holding the methods and precision of data collection constant, a larger sample means larger costs due to the requirements of equipping all household vehicles with the tolling meters and funding their travel budgets. Given the fixed budget, a larger sample size would have reduced the study's ability to create a

realistic travel budget—and therefore, realistic incentive—for the drivers. Too small of a budget would make behavior more difficult to measure and would introduce bias. Premature exhaustion of an Endowment Account balance would not only introduce behavioral bias, but also make more difficult to measure accurately the effect of tolling, and to separate out the wealth effect of Endowment Accounts from the price effect.

For all of these reasons, it is generally better to have high-quality data from a smaller sample than lower-quality data from a larger sample. The team anticipated that the ideal tolling system (given the budget constraints) would equip and monitor the movements of no fewer than 450 vehicles (approximately 275 households) for an average minimum of approximately 12 months per vehicle. A longer data collection period was desirable (all else being equal) to allow more robust analysis once the experiment concluded.

The basic goal of the Traffic Choices Study was to measure the response of traveler behavior to road pricing as if such tolling were in place throughout the road network in the Puget Sound region. The project hypothesized that people would respond to tolling by changing their trip frequency, trip time, and vehicle miles traveled (VMT). The goal of the sample design was to configure the experiment within its budgetary and practical constraints to provide an opportunity to measure demand response consistent with conventional statistical criteria of robustness.

### STATISTICAL CONTROL IN IMPACT MEASUREMENT

The structure of the experiment approximated true experimental protocol, which would expose certain participants (experimentals) to the pricing protocol (the treatment), and not expose others (controls). In a conventional experimental/control design, randomly recruiting experimentals and controls means that the experiment can ignore unobservable, idiosyncratic behavioral parameters because they are assumed to be statistically identical in the two participant groups.

Unfortunately, the implementation of a true experimental/control design was not feasible because of the small sample sizes and the high variance in travel behavior across households. The study could not assume that the presence of unobservable characteristics in controls and experimentals would cancel each other out. To establish a control group, the team instead adopted a “self-control” approach wherein experimental households served as their own controls: that was done by studying behavior before (in a “Baseline” period) and after the implementation of tolling. This design controls for unobservable differences between tastes, preferences, etc. of the experimental and control households. While this offered better control for idiosyncratic behavior of individual households, it introduced the need to control for changes in behavior over time.

### CONTROL FOR SELF-SELECTION BIAS

The experimental design needed to anticipate and control for self-selection and attrition bias. For example, if households with certain characteristics were more likely to enroll or drop out of the experiment (e.g., those whose routes and schedules required them to always take the same road at the same time, independent of the tolls), the results would be biased. The project could not compel participation nor control attrition, and participants could bias the experiment both by joining it and choosing to leave it unless the team took steps to control for these behavioral tendencies.

The main demand that the need for self-selection bias control imposes is the need to gather information on those who chose not to participate, and those who chose to drop out of the program. The latter is relatively easy once the experiment is underway. The former requires that the recruitment process capture information from both those who decline to participate and those who agree to participate.

### SAMPLE ENRICHMENT

Although the project sought to observe drivers' responses to the tolling protocol, in reality many households would not have feasible opportunities to form carpools, take transit, or change the time or frequency of their travel. It is difficult to predict which households have the greatest prospect of change in reaction to tolling.

Carpool formation, however, is known to depend on the number of workers in the household (increases the probability of carpool formation), and household income (reduces the probability of carpool formation). Therefore, enriching the sample with a disproportionate (relative to the population) share of households that have multiple workers and lower incomes would improve the prospects of observing carpooling as a reaction to tolling. Similarly, transit use increases with proximity to transit services and decreases with higher household incomes and number of private vehicles in the household. Hence, the opportunity to observe a transit response to tolling would be increased if the sample were enriched with lower-income households, with greater transit accessibility, and fewer vehicles in the household.

Because of the small number of vehicles that could be outfitted with electronic equipment in the experiment, enrichment for both carpooling and transit use would occur relatively naturally by enriching the experiment with single- and dual-vehicle households. These households would tend to be of lower income, and (for those with multiple workers) more likely to form carpools. Similarly, households with relatively fewer vehicles would also be more likely to use transit, if accessible. Hence, the primary dimension of enrichment not already influenced by the equipment restrictions on the experiment was transit accessibility. Since transit use in the Puget Sound region (as a share of all work trips)

is relatively low, significant enrichment toward those with strong accessibility to transit would be required to test the effect of tolling on mode choice.

Sample enrichment, of course, makes the statistical sample of household used in the impact regressions non-random, violating a condition for estimation of efficient and unbiased coefficients. Special statistical techniques, related to weighted regression, would be necessary to estimate the regression coefficients in an appropriate manner. The weights used in the weighted regression were calculated by comparing the proportion of households with enriched characteristics to households in the population as a whole with those characteristics. In summary, the various desired features of the sample frame interacted with the fiscal and physical limitations of the experiment. [Exhibit E.1](#) (on the following page) shows the basic recruitment goals and constraints.

**Exhibit E.1. Draft Recruitment Goals**

	<b>Recruitment Parameter or Constraint</b>	<b>Measure</b>
	SELF-SELECTION CONTROL VARIABLES	
0	Population proportion with information on household income	100%
1	Population proportion with information on age of head of household	100%
2	Population proportion with information on household location	100%
3	Population proportion with information on persons per household	100%
4	Population proportion with information on drivers per household	100%
5	Population proportion with information on persons driving in congested conditions	100%
6	Population proportion with information on number of vehicles	100%
	CANDIDATE RECRUIT VARIABLES	
7	Number of households with 3 vehicles (target, constrained by OBU max)	5%
8	Number of households with 2 vehicles (target, constrained by OBU max)	40%
9	Number of households with 1 vehicle (target, constrained by OBU max)	55%
10	Proportion of households already carpooling	0%
11	Proportion of households with transit accessibility	50%
12	Proportion of households with at least one worker commuting in peak period and direction on congested facilities within study area	100%
13	Proportion of households with second worker commuting in off-peak period and direction or outside of study area	Max 20%
14	Proportion of households with installation-compliant vehicles	100%
15	Proportion of households with plans to purchase additional vehicles in study period	0%
16	Proportion of households with plans to move in study period	0%
17	Proportion of households with likelihood to change employment status in study period	0%
18	Number of OBUs	Max 500

## APPENDIX BI-F: EXAMPLE BUSINESS ARCHITECTURE

The business architecture describes the structure of the business in relation to customers (i.e., drivers and users), markets, and channels. The business architecture envisioned for the network tolling scenario consists of two basic programs:

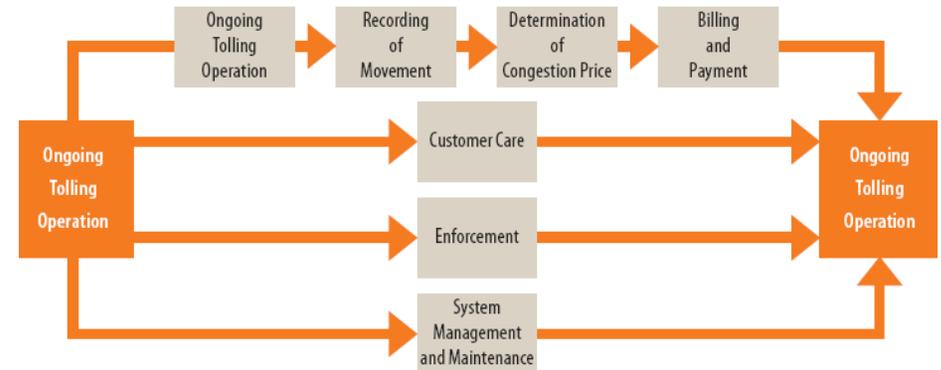
- **Main Program** – The main program is intended for most of the vehicles belonging to residents and companies resident within the four-county region. This main program consists of an On Board Unit (OBU) that is permanently mounted to a vehicle during its entire lifetime. Determination of location and time (and subsequently the number of miles driven by road type and time of day) is based on an OBU which uses GNSS for location detection. Residents and companies resident outside the congestion pricing area (but that frequently enter and travel within the pricing zone) are also included in this main program.
- **Occasional Program** – The occasional program is intended for residents with “non-regular” vehicles (e.g., motorcycles, classic cars), or who choose not to have an OBU installed in their vehicle due to limited usage of the vehicle (e.g., campers). The occasional program is also used for non-residents that drive into and travel within the priced network on an in-frequent basis. The occasional program offers a flat rate charge for the usage of the road network for a specified time period. The exact road usage is not measured or recorded. The flat rate is calculated in a way such that it is more expensive than the congestion charge based on the OBU-based Main Program.

The business processes of the network tolling system are shown in [Exhibit F.1](#) and summarized below.

### REGISTRATION OF USERS

Under the Main Program, the installation of an OBU to a vehicle must be done by an authorized technician. Owners of registered vehicles might have this performed as part of the annual emissions test; or perhaps they can arrange a date for OBU installation with a technician authorized by PSRC. After OBU installation, the vehicle owner/user registers for participation in the main program. It is envisioned that the tolling system

### Exhibit F.1. Congestion Pricing Business Processes



operator will have access to all available data on registered vehicles and their owners via a vehicle licensing database. The user must also specify the desired payment method and provide the associated data (e.g. bank account number), the channel for invoices and the associated data (post address, e-mail address, etc.) and contact details.

For the Occasional Program, the user must register over a variety of possible channels (internet, phone), and must specify the license plate number (and State), address, and the usage period (daily, weekly, monthly, annual). The vehicle category may also be specified; or this information can be acquired (or verified) from the vehicle licensing database.

### MEASUREMENT / RECORDING OF ROAD USAGE / MOVEMENT

As previously noted, under the main program, road usage (distance, road types, time of day) is recorded by the OBU. These OBU data are transferred to the Electronic Tolling Back-Office (ETBO) using a mobile communication network for further processing. Road usage is not measured or recorded under the occasional program, other than a determination of whether or not a vehicle traveled within the tolled road network on a particular day (using Automated License Plate Readers (ALPR)) as part of the enforcement process.

## DETERMINATION OF CHARGE

Costs for road usage under the main program are determined based on the measured and recorded data about road usage (i.e., miles driven by type of road and time of day), coupled with vehicle classification information. The occasional program offers only a flat rate for the usage of the road network for a period of time. The flat rate is based on the vehicle category and the registration period (i.e., day, week, month, and year).

## BILLING AND PAYMENT

Invoices for road usage under the main program are generated (monthly) and can be distributed over several channels (e-mail, internet, postal service) depending on the choice of the user. Payment is possible by several methods (e.g., direct debit, credit cards, debit cards, and checks).

The occasional program requires prepayment via any of the same payment methods used for the Main Program.

## CUSTOMER CARE

Customer care addresses all functions related to road user services and support, including:

- Responding to user questions, including common information and questions (FAQ) about the tolling system and programs (e.g. how to participate, tariffs, billing, etc.), and also questions about an individual participant (e.g. actual status of account)
- Administration of user attributes (e.g. contact details, billing details)
- Handling various types of user complaints

- Exchange of defective OBU's
- Channel management

With respect to the last bullet, channel management provides friendly, flexible and efficient interaction with customers. It is envisioned that a network tolling system would support both inbound and outbound customer contact, with the following contact channels:

- Internet (including mobile devices)
- Telephone (including interactive voice response)
- E-mail
- Fax
- Correspondence by posted letter
- Face to face at customer service centers (also called contact points)

To minimize costs, customer self-services—such as internet services should be made widely available and strongly encouraged for all processes requiring client interaction. Nevertheless, an agent should be available whenever the client requires help.

## ENFORCEMENT

Good enforcement coverage is vital to the success of the system. Appropriate control mechanisms must be implemented to ensure road user compliance. Road users should realize that their compliance is checked, and that non-compliant behavior (e.g., an occasional user who does not register and pay the flat fee) will likely be discovered and penalized.

Automatic enforcement equipment is used to check the compliance of road users

when they enter and are driving within the tolled network, all without immediate human intervention. Stationary and transportable / mobile enforcement setups are utilized. Photographs are taken of each checked vehicle, and automatic license plate recognition (ALPR) equipment determines the vehicle identification. The license plate number is sent to the enforcement back office (EFBO), along with location and timestamp, which checks all available information (enforcement and usage records, occasional program registration status) for consistency and compliance. In the event of a possible violation (e.g., there is no record that the vehicle owner / driver paid the congestion charge, they paid for the wrong category of vehicle, condition of the license plate prevents an automated read with the required degree of certainty), the EFBO sends a notification to the ETBO for subsequent action. Some or all of the following steps may be necessary in order to process and send an administrative bill to a non-compliant user and receive payment:

- Manual check of the number plate of the violator using the evidential record, which may consist of a color picture, infrared picture, plate number and state, timestamp of the enforcement case, and place / location of the enforcement case.
- Inquiry concerning the number plate of the violator
- Preparation of the evidential record together with the administrative bill for the violation registered person.
- Sending out the administrative bill and possible follow up.

A block diagram of the tolling system is provided in [Exhibit F.2](#). The major elements and building blocks of the system are described in greater detail (including assumptions on which the cost model is based) below.

### ELECTRONIC TOLLING SYSTEM

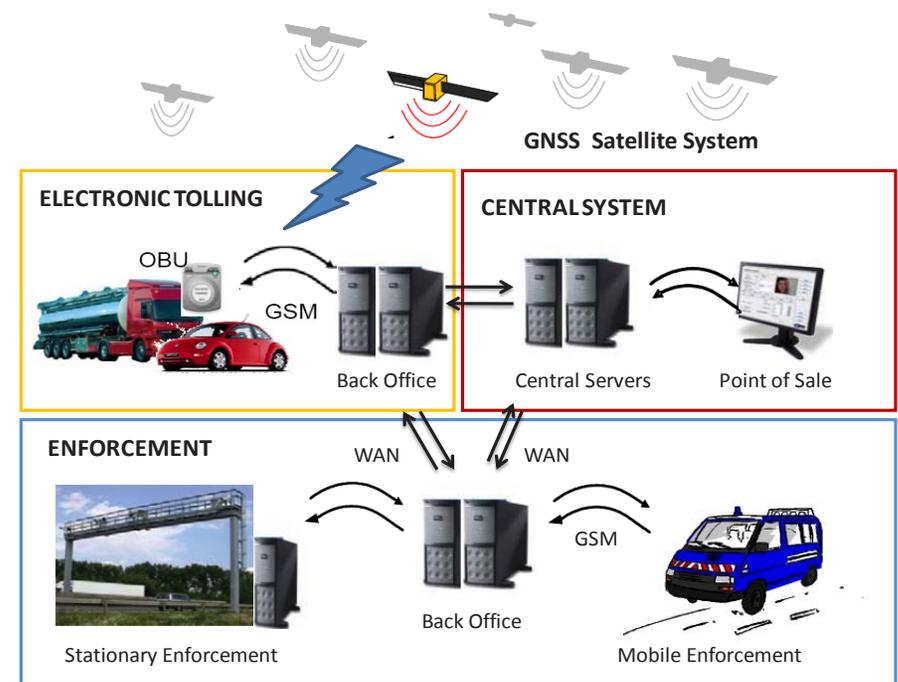
The electronic tolling subsystem is the operational core of the toll solution. Its main task is to collect vehicle road usage information from the OBU's. From the collected road usage information, the charges are calculated and applied, using a flexible tariff model that is capable of handling different tariffs dependent on date and time, location and type of road, and vehicle categories. The accumulated charge information is provided to the Central System.

#### On Board Units (OBU)

The road usage information for the Main Scheme is collected by use of GNSS (GPS) location information and geographical data (geo data), using an OBU installed in each vehicle. It is assumed that the cost of purchasing and installing the OBU (and any repairs / replacement of defective OBU's) will be borne by the system; not by the users. By not requiring the road users to pay for the OBU themselves – coupled with a tariff structure that significantly favors the Main Scheme as compared to the Occasional Scheme in terms of user costs – it is envisioned that this will result in a large percentage of the road users opting for the Main Scheme. In general, there are two approaches for the processing and distribution of data between the OBUs and the System Back-Office:

- **Thick Client** – This approach consists of an intelligent On Board Unit that contains the latest version of all necessary tolling information (road user charging tariffs), geographical data (road categories, boundaries), and processing power to calculate the charge for each trip. Only the amount of the trip charge is transmitted to the Back-Office, which takes care of the processes associated with debiting the account and management.
- **Thin Client** – With this approach, the OBU does not contain any geographical (map) information, and only performs a minimum of processing. It acts like a simple sensor providing position information, which is transmitted (in an encrypted format) to the Back-Office. There, the information about tariffs, road categories etc. is stored and applied to calculate the trip charges.

### Exhibit F.2. High Level Architecture for Road Network Tolling System



[Exhibit F.3](#) (on the following page) summarizes the main advantages and disadvantages of both approaches.

Both a thin and thick client approach can work in the same system. For the purpose of the cost model, it is assumed that a thin client approach will be used, resulting in lower unit costs for OBUs). That said, some users may be willing to pay the additional cost of a “thick client” OBU and the increased privacy and enhanced user displays. Accordingly, the final design for a road network tolling system should accommodate both approaches. Other costs associated with OBUs include the following:

- **OBU Installation** – As previously noted, it is envisioned that users will have their OBUs installed as part of the annual emissions test; or they can arrange a date for OBU installation with a technician authorized by PSRC. Owners of large fleets could optionally become authorized for storing and installing their own OBUs.

- Training of authorized technicians for the installation of OBUs
- Replacement of defective OBU's (the cost model assumes that 5% will need to be replaced annually)
- Storage and distribution of spare OBUs

**Central System / Back Office**

The subsystems Electronic Tolling, Central System, and Enforcement share a common central infrastructure which is distributed over 2 separated highly secure data centers. All external physical interfaces have redundancy built into each data center. The data centers themselves are connected over redundant lines (see Exhibit F.4 on the following page). The infrastructure of the individual sites is designed in a way so that it can handle the whole load in the case of one site failing completely.

As previously noted, the electronic tolling subsystem is the operational core of the system. Its main task is to collect vehicle road usage information based on the OBUs. From the collected road usage information, the charges are calculated and applied, using a flexible tariff model which is capable of handling different tariffs dependent on location / roadway type, date and time, and vehicle categories. The **Electronic Tolling Back Office (ETBO)** is structured into several applications to divide the system into easy manageable parts with clear interfaces. This modular design ensures good maintainability.

The **Enforcement Back Office (EFBO)** receives charging violations in the form of enforcement records transferred from the roadside units. The

**Exhibit F.3. Advantages of Thin and Thick Client**

	<b>Thin Client</b>	<b>Thick Client</b>
<b>Operational Cost</b>	Relative low, since OBUs are “dumb” devices, resulting in lower unit costs and lower failure rates. Little difference in communication costs.	Relatively high, since OBU's are intelligent, resulting in higher unit costs and higher failure rates. Little difference in communication costs.
<b>Updates / Flexibility of Tariffs, Roads, Schemes, etc</b>	High Flexibility. Not necessary to update data in OBU since all pricing and geo data are kept centrally.	All OBUs need to be updated (downloaded via wireless communications) for every change in scenario of tariff pricing.
<b>Privacy</b>	Requires encryption of trip data for transfer to Back Office; and trusted Third Party to ensure user privacy	High - only road charge data (i.e., no trip location information) are transferred to Back-Office
<b>Value added services</b>	OBU may be used as a “probe”. Traffic flow information can be easily deducted and generated at central.	Generation of traffic flow data is more cumbersome
<b>Evolution of charging algorithms</b>	Charging and map matching are in the Back Office, easily accessible and therefore can be more easily evaluated and improved.	Map matching algorithms are in the OBU, hence more difficult to access, evaluate and improve.
<b>User Displays (vehicle position / charges)</b>	Generally not feasible.	Feasible

EFBO performs violation process as discussed in the previous section on Enforcement. The EFBO also monitors the enforcement field equipment, providing information about faults and alarms of equipment and devices, system performance, and statistic data. Detailed historical logs are maintained for all components.

The **Central System (CS)** handles back office processing. Whereas usage data and enforcement data flows into the system, the CS produces invoices and fines, and provides means for customer interaction to the system. A Management Information System provides the necessary data to account for its performance. Vehicle data can be verified through an interface

to the vehicle registration database. The customer registration includes the type road usage charging (i.e., Main Program use of OBU, or Occasional Program). Occasional Program users that have properly registered are included in a “white list” of vehicles that do not use OBU and therefore do not store any usage data in the deleted. In case of violation, the image is collected to the EFBO for further processing.

Back office systems are separated by internal firewalls. Back office communication is also validated by intrusion detection system. None of the back office servers are accessible directly from internet. Traffic from the internet portal is sent (via security systems) to load balancers and then to application servers. Application

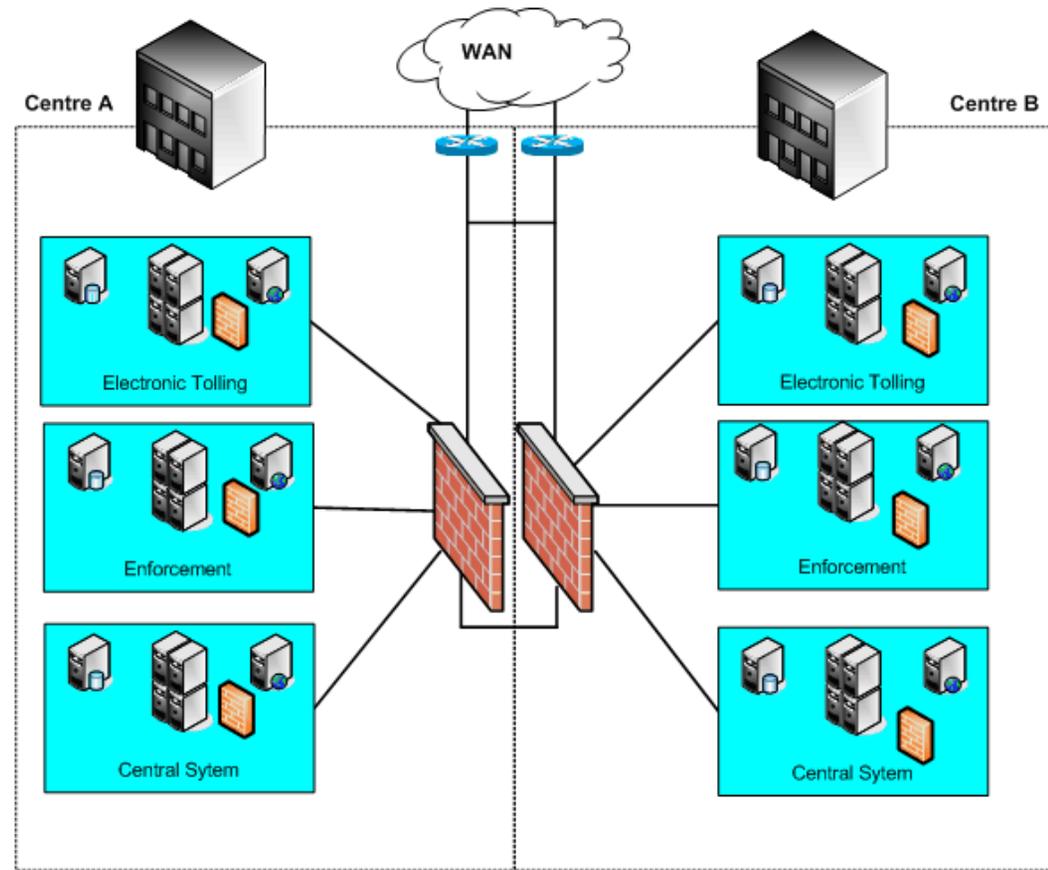
servers communicate with database servers via internal security systems. This protects all internal servers from invalid access.

### Enforcement

Enforcement is essential to the success of a road tolling system, and especially the Occasional Scheme. There are several attributes that must be considered in developing the enforcement subsystem:

- The enforcement process must be automated to the greatest extent possible, and have high throughput. Manual processing steps result in slow processing (threat of cumulative backlog), threat of high error rate (false positives, user acceptance!) and in high operational costs.
- It is nearly impossible (i.e. very expensive) to achieve 100% enforcement coverage for the entire charging area. Given the large number of roadways, intersections and interchanges, and alternative paths within the charging area, the installation of enforcement equipment to cover each and every road and possible trip would be cost prohibitive. Enforcement activities and equipment should focus on the major roadways that carry the greatest amount of traffic.
- It is nearly impossible (i.e. very expensive) to achieve 100% enforcement coverage for a given road cross section. For very busy roads such as freeways and major arterials, the frequency of vehicles passing is too high to check them all with a high degree of reliability. The equipment can only sample road user behavior.

### Exhibit F.4 Central System Architecture



- Effective enforcement is not achievable with fixed enforcement locations only. A large part of the road network within the four – county region consists of minor arterials and side streets where (as noted in a previous bullet) it is not cost-effective to install fixed enforcement equipment. Accordingly, it may be easy to avoid fixed enforcement equipment locations by users who are so inclined (i.e., those individuals without an OBU or who have not registered

for the Occasional Scheme). Transportable and mobile enforcement equipment should be used to cover these other roads as appropriate.

The cost model for the road network tolling system is based on an enforcement scheme that operates with automatic license plate recognition (ALPR) as the primary input from the roadside, with evidential photographs taken simultaneously. ALPR technology for

congestion pricing enforcement is being successfully used in London. The ALPR sites are typically installed just inside the entrances to the London congestion charging zone. The ALPR functions are provided by a fully integrated solution that is a combination of a color overview camera plus a monochrome IR camera with an integral LED illuminator to acquire high quality IR images of license plates. The internal ALPR Processor employs dedicated hardware for image pre-processing and plate finding coupled with an embedded processor. It also has local storage capacity for thousands of vehicle records.

The outcome of the ALPR process is a Summary Record which contains the time-stamped vehicle plate number, and an Evidential Record which contains the Summary Record plus the image set (Exhibit F.6). Each record is marked with a value between 0 and 99 indicating the confidence level of the ALPR process. Evidential Records are authenticated and encrypted via a secure key handling enforcement session protocol and transmitted to an enforcement back office (EFBO) back location they are automatically compared to one or more databases to determine if pre-payment has already been made or if the vehicle is “exempt”, in which case no further action is required and the records are deleted from the camera. Otherwise, a fine is assessed and a bill is prepared and mailed.

**Stationary Enforcement**

The cost model assumes that fixed enforcement assemblies will be installed along the freeways (e.g., I-90, I-5, I-405, Routes 520 and 99) and major arterials (e.g., Routes 202, 203, 900, 509, 9, 527) where high traffic density results in need for high throughput, and where it is difficult or inconvenient for a driver to avoid passing the check point. The permanent installation enables optimization of equipment and communication facilities, ensuring good coverage on high traffic frequency locations. The stationary assemblies will be installed at the entrances to the road pricing area and in the vicinity of major interchanges and intersections (e.g., SR 520 / I-405, I-90 / I -405, SR 520 / I-5, I-90 / I-5) within the zone.

Exhibit F.7 (on the following page) is a schematic of the roadside equipment for stationary enforcement along the freeway. This assembly typically consists of several components such as sensors for determination of the vehicle category (length, width, number of axles, trailers ...), ALPR equipment for reading the license plate electronically, and a cabinet

**Exhibit F.6. London Summary Record from ALPR**

Location of camera	test site description field	Read Confidence	093
Vehicle Number Plate	NL54USV	Country of origin	UK
ANPR ID	TW13_2	Lane	2
Source	WEZ	Session ID	000014367
Date Time of Capture	20050511 10:49:12		
Frame Counter	000002287206695		

**Plate Patch**

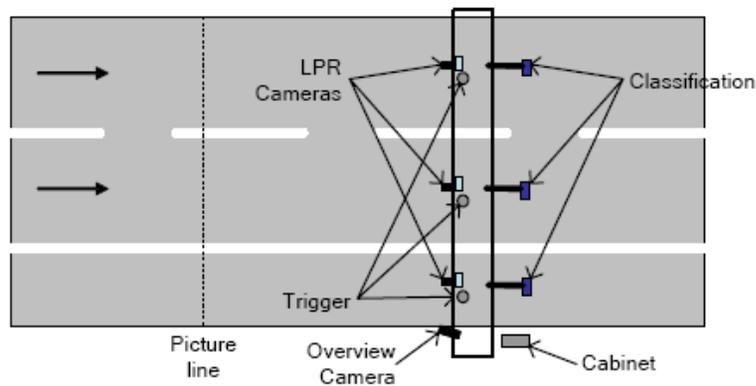
**Monochrome Image**

**Colour Contextual**

**Colour Contextual Before**

**Colour Contextual After**

MAYOR OF LONDON

**Exhibit F.7. Schematic of Stationary Enforcement Assembly**

containing a gantry server for handling communications, storing evidential records until evaluated and controlling the other devices on the gantry. Along the arterial streets, ALPR cameras will be mounted on poles similar to what is used in London ([Exhibit F.8](#)). Classification detection is not included for the arterial assemblies.

### Transportable Enforcement

This type of enforcement is selected to get a high visibility of enforcement while checking the most significant parameters in order to determine compliant behavior. Transportable enforcement is purely based on ALPR. The transportable enforcement equipment consists of a compact setup that can be placed at the roadside. A pole carries cameras for taking evidential photographs and for ALPR. The base of the pole contains the gantry server and infrastructure components (e.g. power supply). The equipment is designed and dimensioned to operate autonomously for several days, after which the data must be transferred to the EFBO for further processing and the power supply must be recharged. Transportable enforcement offers several advantages, including:

- No long term “learning effect” by drivers as to how they bypass and avoid enforcement
- The ability and option to place the stationary portable enforcement at each and every place of interest.
- No additional gantries have to be erected.

**Exhibit F.8. Pole-Based ALPR / Enforcement Installation in London**

### Mobile Enforcement

Mobile enforcement equipment consists of ALPR equipment mounted on top of an enforcement vehicle, and a terminal inside the vehicle for accessing road user data in the central system (see [Exhibit F.9](#) on the following page). Dedicated staffs operate the mobile enforcement units. Mobile enforcement has the same advantages as transportable enforcement, but with even greater flexibility – the moment of surprise is high, it is impossible to predict for offenders

### Enforcement Back Office (EFBO)

The EFBO consists of the central components responsible for supporting the enforcement field components. It handles all data transfer, retrieving needed information from the central system, compiling and delivering enforcement records to the central system. It distributes black lists to the field components and collects messages about blacklisted vehicles.

Due to the high number of vehicles in the system, it is important to avoid manual processing to the greatest extent possible. The system first determines whether a vehicle with its recognized license plate is in violation.

The matching of the ALPR-information with the payment information is done on basis of raw ALPR-data, irrespective the reliability level. This could even be with one character of the license plate not read or misread.<sup>12</sup> In a second step, the violation is checked with the reliability of the ALPR result taken into account. Violator license numbers that are read and classified with a high reliability will be processed fully automatically. Violator license plate numbers that are read with low reliability or that cannot be classified automatically will be processed manually.

Manual post-processing is inevitable for a certain percentage of the enforcement records collected. For this task, workplaces must be set up within the EFBO and equipped with the necessary data access and support features. This equipment is basically a terminal for accessing and editing enforcement records and retrieving related information. Training and supervision processes ensure reliable and fair demeanor of the enforcement personnel. Other EFBO activities and services are summarized below:

- Delivering Enforcement Records - All information (photos, license plate numbers etc.) of a suspected violation are compiled and delivered to the central system automatically. No manual checks are performed.
- Checking of Enforcement Records - In the case of disputes or for other reasons, it is sometimes necessary to perform further checks on selected enforcement records. The enforcement subsystem offers support for these tasks including delivery to

manual enforcement back office terminals, where manual checks help to validate the correctness of suspected violations. The original record plus a summary of the checking conclusions are delivered as the result.

- Prosecution of Blacklisted Vehicles - Additionally to collecting enforcement records, the equipment also serves for tracking down offenders. This is facilitated by distributing lists of vehicles to the field enforcement components (stationary and mobile units). These (and the personnel involved) are therefore able to look out for suspects. Alarms are triggered and transmitted as the result of this service as soon as blacklisted vehicles or OBUs pass enforcement stations.

#### Enforcement for OBU-Based Vehicles

The operation of the ALPR – based enforcement subsystem described above is focused on potential violations of the Occasional Scheme. Enforcement activities are also directed towards the OBU – equipped vehicles, including:

- Data Mining - Information collected in the central system can yield suspicious patterns. Sudden reductions in road usage, gaps in tracking data and other types of behavior can be an indication that charging violations are committed.
- Checking of OBE History - The OBU can hold a history of status and usage records. Tracking information (with higher granularity) held in the OBU might be checked during enforcement, on cancellation or re-installation

#### Exhibit F.9. Mobile Enforcement Vehicle in London



in a new vehicle, or in the course of the regular vehicle inspection. This information can lead to indications of non-compliant behavior.

- Comparison of Odometer Reading with Toll Records - In the course of the regular vehicle inspection, or during manual enforcement, an odometer reading can be taken and compared with the mileage registered in the tolling system.

#### Data Communication

The communications infrastructure is a key element of any road pricing system. If the network cannot properly support the exchange of information between system elements (e.g., OBUs, enforcement / ALPR field devices, and central systems / back offices, it can inject a serious constraint on the overall operation, resulting in lost revenue and reduced system credibility on the part of the road users. The bandwidth (i.e., how much information can be transmitted) and the latency (i.e., are the transmissions received in a timely manner) are

<sup>12</sup>It is noted that the ALPR subsystem for the London congestion charging achieves a 93 % capture rate with an 85% overall accurate read.

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major, and interrelated, considerations when designing and operating a communications subsystem. The following communications infrastructure and services are necessary:

- Wireless network services for communication between the OBUs and the Electronic Tolling Back office (ETBO). It is envisioned that **General Packet Radio Service (GPRS)** – a Mobile Data Service available to users of Global System for Mobile Communications (GSM) – will be used. GPRS has become ubiquitous wireless data service, available now with almost every GSM network. GPRS is a connectivity solution based on Internet Protocols that supports a wide range of enterprise and consumer applications. GPRS currently provides data rates from 56 up to 114 Kbps.
- Communications network between enforcement stations and the Enforcement Back Office (EFBO). ALPR information sent back to the back office for each captured plate includes a color and infrared picture, a detected and digitized number plate, time stamp of the picture, and the address / location where the picture was location. Based on the London experience, the size of this data file, including photographs, is 140 kb for each plate capture. It may not be necessary to transmit the pictures for each capture; but to only transmit the pictures upon request from the EFBO – such as in the case of a possible violation, where there is the need to include a picture as part of the evidential record. Without the pictures the data file is 50 kb. As a fair amount of latency can be tolerated, the wireless GPRS network

can also be used for this network (especially for the mobile enforcement). It is envisioned that some of the stationary stations may be located in such a manner that existing communications networks (e.g., Washington DOT fiber along the interstates) can be used for communications, provided appropriate security measures can be implemented.

- Communications between ETBO, EFBO, central system, and redundant locations. As these are fixed (i.e., non-mobile locations) requiring large bandwidth, it is envisioned that some sort of leased (and secure) circuits will be used for this network.

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# Appendix B2: Issue Paper

Issues Related to VMT and Fuel Tax Revenues

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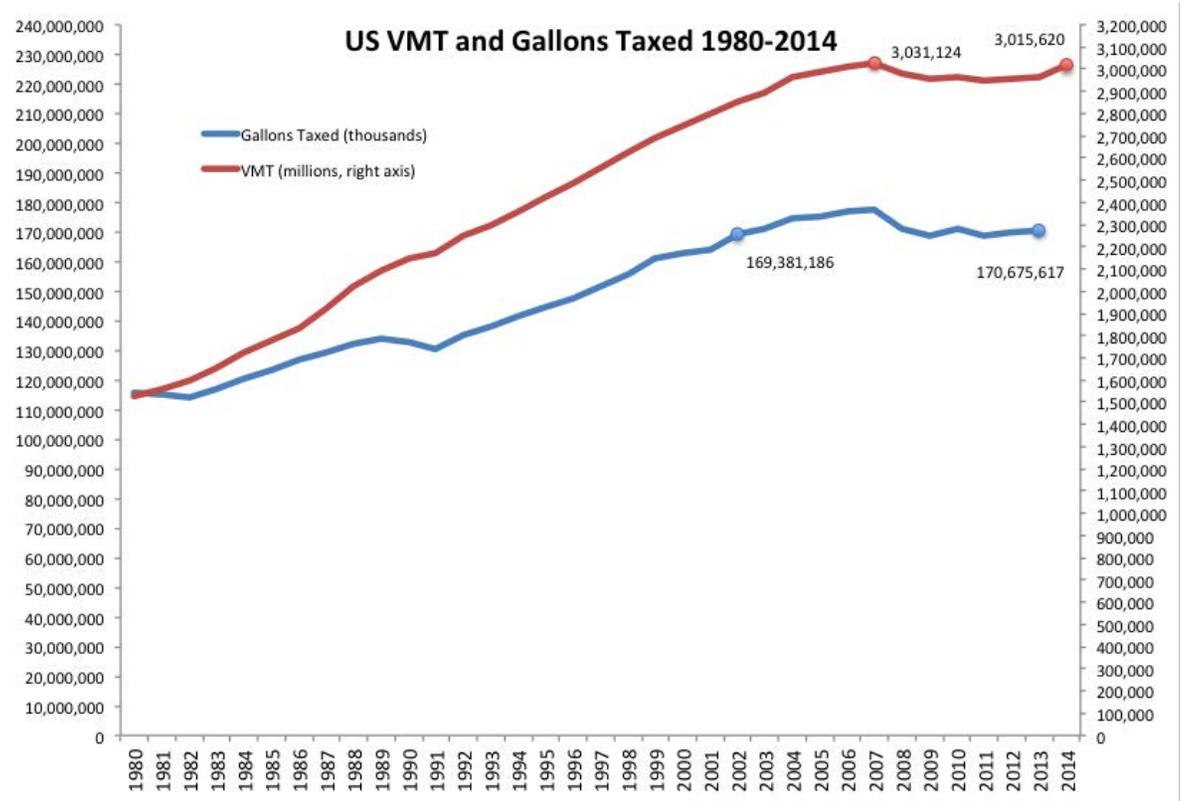
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## OVERVIEW

In recent years, people who study traffic data and travel behavior have noticed that vehicle miles traveled have not been increasing the way one would expect given historical relationships between population, economic activity, and vehicle miles traveled (VMT). Nate Silver humorously summed it up in 2009 when he said, “This is surely one of the signs of the apocalypse: Americans aren’t driving as much as they used to.” Silver goes on to point out that, “If there have been two seemingly immutable trends for the American consumer, they’re that he’s eaten more every year and driven more every year. The late 1960s are sometimes assumed to be the height of car culture. But in January 1970, the average American drove only about 393 miles in his vehicle, or about half of what he drove every month until recently.”<sup>1</sup>

As the nation slowly emerged from recession, transportation agency officials around the country began noticing that fuel-tax revenues weren’t recovering as fast as expected. The conventional wisdom was that because the recession was unusually deep and the recovery unusually slow, VMT and fuel-tax revenues were taking longer than usual to turn around, but they would make up for lost time real soon. Real soon still hasn’t arrived and many agencies are beginning to accept that there may have been a fundamental shift in travel behavior, one that began before the recession started and that is likely to continue.

Figure 1: VMT and Gallons Taxed in US 1980 to 2014



Source: FHWA Office of Highway Policy Information

Figure 1 shows VMT and taxed gallons of fuel nationwide since 1980. Nationally, VMT peaked in 2007 and was still below that peak five years later in 2012. While taxed gallons of motor fuel shows the same pattern of increasing steadily until 2007 and then falling and flattening out, taxed gallons did not grow as fast since 1980 as VMT and fell more sharply after 2007. As of 2012, taxed gallons had just surpassed 2002 levels, even though population and employment had both increased in the intervening ten years.

The growing gap between the two lines is a result of improved average fuel economy. As of mid 2014 total VMT nationally was estimated to be increasing once again.

This paper examines what happened to VMT and VMT per capita nationwide and in Oregon over the last 35 years, why VMT per capita increased steadily, then began falling, rising once again and what it all means for fuel-tax revenues.

<sup>1</sup>Source: FHWA Office of Highway Policy Information

## ISSUES RELATED TO VMT AND FUEL TAX REVENUES

### WHAT DETERMINES VEHICLE MILES TRAVELED (VMT)?

Several factors combine to determine how many miles vehicles will travel in a period of time. These factors are both demand-side factors and factors that effect the supply and price of vehicle related travel.

- **Population.** The number of people who travel directly determines the amount of travel, all else being the same.
- **Trips per Person.** The number of trips each person makes is influenced by employment, the amount of shopping and other non-work activity undertaken and trip chaining, or how many activities are combined into a single trip. The number of automobile trips each person makes is influenced by the availability and cost of alternative modes and the proximity of home, work, shopping, and other locations.
- **Miles per Trip.** The length of trips is determined by the proximity of home, work, shopping, and other locations, which is influenced by the choice of residential location and the choice of workplace location and activity destinations for shopping and other activities.
- **People per Vehicle.** Vehicle occupancy is inversely related to VMT and it tends to be lower for commuting trips than for other types of trips.

These factors that determine VMT may be expressed as an equation:

$$\text{VMT} = \text{population} * \text{trips per person} * \text{miles per trip} / \text{people per vehicle}$$

By definition, per-capita VMT is VMT divided by population, so:

$$\text{Per-Capita VMT} = \text{trips per person} * \text{miles per trip} / \text{people per vehicle}$$

### HOW VMT IS AFFECTED BY VEHICLE OPERATING COSTS?

VMT is influenced by vehicle operating costs, or specifically the effective cost of operating a motor vehicle. Vehicle operating costs are a function of both the price of motor fuels and the relative fuel efficiency of vehicles. Although CAFÉ standards and other regulatory efforts will have an effect on fleet efficiency over time, their effect is only on new additions to the fleet. Household purchasing behavior also causes the fleet average fuel efficiency to lag CAFÉ standards significantly.

The higher purchase cost of more fuel-efficient vehicles, and the reduced primary- and secondary-market value of less efficient and older vehicles, causes less-fuel efficient vehicles to remain longer in the fleet. The interaction of many factors influences utilization of vehicles of various types and efficiencies and, hence, the effective fuel and maintenance cost of vehicles in the fleet.

The short- and long-run trends in fuel efficiency and fuel cost are affected by underlying (time-related) trends and fuel costs per gallon. In the long run, the fuel component of operating cost per vehicle mile grows less rapidly than fuel costs due to decreases in the quantity of fuel used per mile.

It is generally anticipated that the adjustment process of fuel costs per vehicle mile traveled is a slow one, since material changes in driving behavior, the vehicles employed, and other factors will take time to evolve. It is also understood that the effects will be difficult to extract from actual data due to the high degree of noise arising from imperfections in measuring such quantities as VMT, fuel prices and their net effect on the fuel cost component of operating expenses. Finally, it is likely that the passage of time may influence the evolution of driving behavior as new technologies become available, demographic and working conditions change, etc. For these reasons forecasting vehicle operating costs and the effect of these costs on VMT is challenging.

### HOW ARE VMT AND THE ECONOMY RELATED?

Vehicle use plays a role in both economic production and consumption.

The movement of goods is an important part of many industry production functions. But it is also true that the movement of people (labor), especially within metropolitan regions, is hugely important to the production possibilities of many other industries. And people are also consumers that need access to markets.

Formal studies of the relationship between the amount vehicle use and the economy are few.<sup>2</sup> What research has been done strongly supports two-way causality between auto-mobility (and fuel efficiency) and the economy. The phenomena influence each other, and the paths of these influences are not always direct. Changes in technical efficiency dominate the historical environment. For example, high demands for vehicle use likely causes changes in fuel technology and thus limits the effects of fuel costs

<sup>2</sup>Driving the Economy: Automotive Travel, Economic Growth, and the Risks of Global Warming Regulations. Prepared by Dr. Randall Pozdena for the Cascade Policy Institute, November 2009.

on the economy in the long run. As a result of the complex links between auto-mobility and the economy it is the case that VMT is less sensitive to sudden changes in fuel costs than it is to sudden changes in the overall demand in the economy (as might be measured by GDP).

As the economy slows so does demand for the movement of goods and people. But the rebound of VMT that follows the economic recovery can be slow to materialize. Since energy usage is memorialized in long-lived assets such as the current stock of vehicles anything that increases energy costs results in a reduction in the value of “older” capital. This slows the penetration of energy-saving technology thus keeping the relative costs of vehicle use higher than they might be otherwise. All this makes forecasting future VMT a particularly challenging exercise.

### WHAT WAS HAPPENING WITH VMT BEFORE 2000?

Throughout the second half of the last century, with minor setbacks during economic downturns, VMT grew faster than population. The average person traveled more and more miles each year as per-capita VMT increased. Several causes have been cited by researchers, including:

- **Increased labor force participation**, especially by women. The baby boom generation moving through their working years also raised the proportion of the population of working age and the number of workers. Workers tend to drive more than non-workers and are more likely to drive alone, so as the proportion of the population that works increased, so did per-capita VMT.
- **Increasing distances** to work, shopping, and other activities. With suburbanization and decreased housing density, people ended up living farther from work and commercial centers.<sup>3</sup> Shopping activities shifted from local shops to regional shopping centers and big-box stores.
- **Increasing non-work trips**. The baby boom generation not only worked more, they also shopped more, were more likely to eat out, were more likely to drive their kids to school, and took their kids and themselves to more activities than previous (or future) generations. Driving to the gym to ride a stationary bike became a common thing to do.

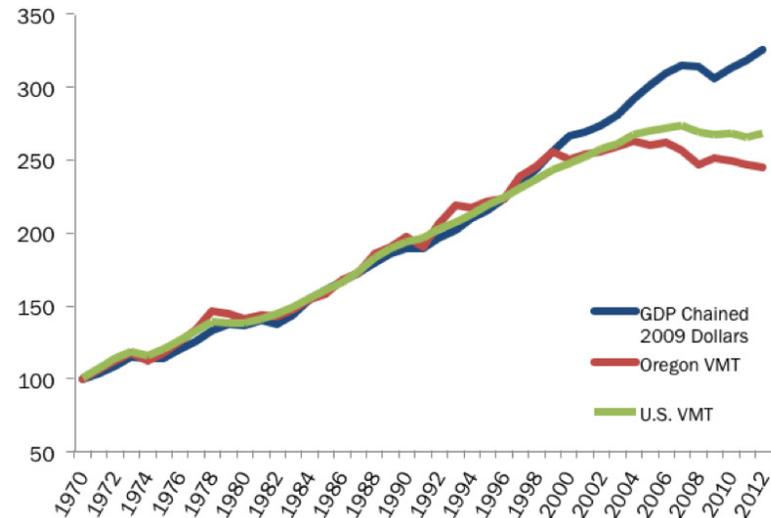
<sup>3</sup> Ewing, R., M. B. Deanna, et al. (1996). “Land Use Impacts on Trip Generation Rates.” *Transportation Research Record*(1518): 1-6.

<sup>4</sup> Handy, Susan, Xinyu Cao, Patricia Mokhtarian. “Correlation or causality between the built environment and travel behavior? Evidence from Northern California,” *Transportation Research Part D* 10 (2005) 427.444.

<sup>5</sup> Litman, Todd. “The Future Isn’t What It Used To Be: Changing Trends And Their Implications for Transport Planning,” *Victoria Transportation Policy Institute* (Aug. 2014): 13, <http://www.vtpi.org/future.pdf>.

<sup>5</sup> McCahill, Chris and Chris Spahr. “VMT Inflection Point: Factors Affecting 21st Century Travel,” *State Smart Transportation Initiative* (Sept. 2013): 2, [http://www.ssti.us/wp/wp-content/uploads/2013/10/VMT\\_white\\_paper-final.pdf](http://www.ssti.us/wp/wp-content/uploads/2013/10/VMT_white_paper-final.pdf)

**Figure 2: GDP and VMT in the US and Oregon, Percent of 1970**



Source: ECONorthwest, Federal Highway Administration, and Bureau of Economic Analysis

- The **share of trips made by automobile increased** as distances increased, density decreased, and transit service deteriorated. The proportion of trips within feasible walking or biking distance fell, in many areas to near zero.

Per-capita vehicle ownership also grew throughout the late twentieth-century because of rising wages, lower fuel prices, and suburbanization.<sup>4</sup> Then something happened. In Oregon, the change was underway before the turn of the century. Nationwide, it became obvious later, but still in advance of the economic recession. Per-capita VMT stopped increasing and began to fall.

### WHAT HAPPENED TO VMT AFTER 2000?

VMT has always bumped up and down with economic activity through the business cycle, but those bumps were small, relative to the overall trend, and VMT had always returned to the trend line. But as [Figure 2](#) shows, VMT diverged from economic activity around the year 2000 and never returned to the previous trend line.<sup>5</sup>

Figure 2 (on the previous page) also shows that the relationship between VMT and GDP in Oregon changed sooner and more drastically than in the rest of the US.

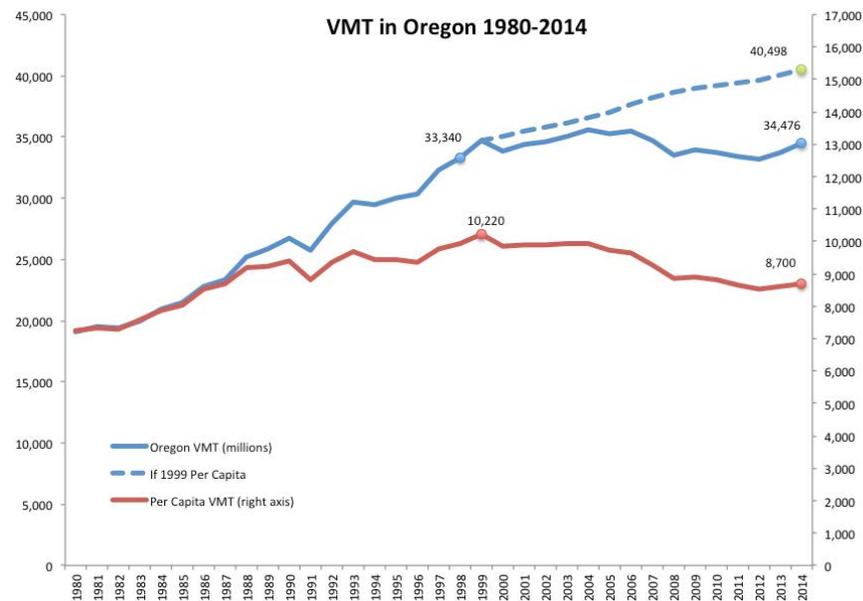
Figure 3 shows VMT and per-capita VMT in Oregon since 1980. VMT peaked earlier in Oregon than in the rest of the nation (2004 rather than 2007) and had finally passed 1998 levels in 2014. In Oregon, per-capita VMT peaked in 1999 and has declined ever since. By 2014 it was back down to where it was in 1987.

Figure 3 also shows where VMT would be in 2014 if per-capita VMT hadn't declined. If per-capita VMT had simply stopped growing in 1999, VMT would be 17 percent higher in 2014. If per-capita VMT had continued growing, VMT would be still higher.

There appears to have been a fundamental shift in per-capita VMT that started in about 1999 in Oregon and a few years later in the rest of the US. It is likely that several factors combined to change how much driving Americans do. Those factors include:

- **Demographic shifts.** Baby boomers, who had filled the ranks of commuters and soccer moms, saw their kids leave home and began retiring.<sup>6</sup> The generation now in their peak driving years is significantly smaller than the baby boom generation that preceded them and the millennial generation that follows them.
- **Land use patterns changed.** Suburbanization slowed, especially in Oregon. New infill and redevelopment exceeded greenfield development at the fringes of urban areas. Urban and suburban schools became more similar and urban-area residents with school-age children felt less need to move to suburban school districts. In Oregon, these changes were promoted by policy. Forty years of deliberate planning, beginning with statewide Goal 12 in 1973, along with the Transportation Planning Rule, have succeeded in reducing growth in VMT. Current statewide policy, under the Oregon Sustainable Transportation Initiative (OSTI) seeks further reductions in greenhouse gas emissions.
- **Transit service** improved. After decades of deteriorating transit service cities around the country began making investments in improving service.

Figure 3: VMT and Per-Capita VMT in Oregon 1970 to 2012



Source: ECONorthwest, Federal Highway Administration

- Opportunities and technology for **telecommuting** improved.<sup>7</sup>
- **Online shopping** became prevalent.
- The time cost of travel continued to increase with congestion in urban areas. And changes in **vehicle operating costs** have both a short-term and long-term effect on travel.
- **Travel behavior** changed in subtle ways. Trip chaining became more common, shopping trips became less frequent, and people became more likely to choose nearer destinations. Each of these changes was small and slow, but over time and over the entire population, fewer trips and fewer miles per trip added up to fewer miles per person per year.
- **More demographic shifts.** The next large generation, the millennials, who are now 15 to 30 years old, will be entering their peak driving years soon. By itself, this will put upward pressure in per-capita VMT. However, market researchers have concluded that the millennial generation has

<sup>6</sup>McGuckin, Nancy and Jana Lynott, "Impact of Baby Boomers on U.S. Travel, 1969 to 2009," AARP Public Policy Institute (Oct. 2012): 7, [http://www.aarp.org/content/dam/aarp/research/public\\_policy\\_institute/ljv\\_com/2012/impact-baby-boomers-travel-1969-2009-AARP-ppi-liv-com.pdf](http://www.aarp.org/content/dam/aarp/research/public_policy_institute/ljv_com/2012/impact-baby-boomers-travel-1969-2009-AARP-ppi-liv-com.pdf).

<sup>7</sup>Sangho Choo and Patricia L. Mokhtarian (2007). "Telecommunications and travel demand and supply: Aggregate structural equation models for the US," Transportation Research Part A-Policy and Practice. 41 (1), pp. 4-18.

different values and aspirations than the baby boom generation did. They are less likely to aspire to a big house on a big lot in a distant suburb. They are more likely to have a positive view of active modes and of transit and less likely to enjoy drive-alone commuting.<sup>8</sup>

A survey conducted by Zipcar shows 50% of Millennial respondents preferred to drive less than their older counterparts, and 35% of Millennials also reported they are actively seeking alternative modes of transportation.<sup>9</sup>

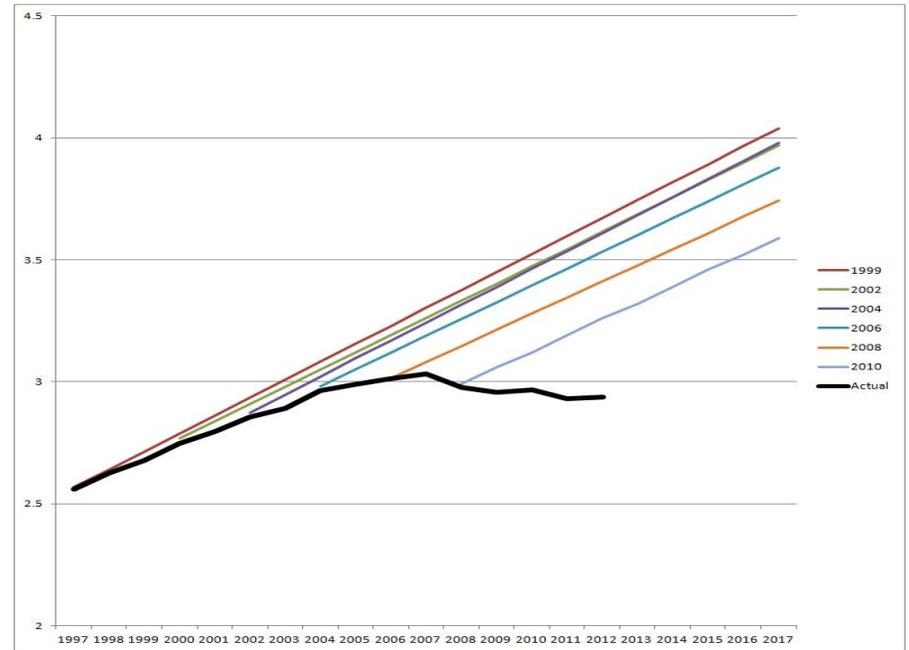
While it is almost certain that millennials will drive more as they age into their peak driving years, the millennial generation, which is now 15 to 30 years old, drives fewer miles per person per year than did either the baby boom generation or Generation X before them. It is therefore also likely that they will drive less than previous generations did. In addition to driving less, members of the millennial generation are less likely to hold a valid drivers license and less likely to own a car than were members of previous generations when they were the same age.<sup>10</sup>

Transportation researchers have been examining these phenomena for at least five years now, and with each passing year, the consensus that something has fundamentally changed grows. Long-run VMT forecasts are being questioned and different forecasting methods applied. Figure 4 shows what has happened as states have repeatedly applied the forecasting methods prescribed for the Highway Performance Monitoring System (HPMS). Those state forecasts are summed together and reported to Congress every other year. The heavy line in Figure 4 is estimated actual VMT reported after the fact and the lighter lines are the forecasts.

The forecasting problems highlighted in Figure 4 have led some states to revise their VMT forecasting methods. For example, Washington changed the methods used in their long-run VMT forecast. Figure 5 (on the following page) shows their current, adopted forecast along with their forecast from a year earlier.

In the context of serious policy efforts related to greenhouse gas emissions and smart growth, improved forecasting methods that are capable of incorporating observed changes in traveler behavior along with the effects

**Figure 4: Actual and Forecasted VMT**



Source: State Smart Transportation Initiative (SSTI), Federal Highway Administration

of new and proposed policies, laws, and regulations are necessary to design sound policy and to plan for their effects on travel, land use, economic development, and productivity.<sup>11</sup>

Other factors that could affect per-capita VMT, but have had less influence, include:

- Vehicle occupancy.** The average occupancy for vehicles on commute trips is very near one and well under two for other trip purposes. Reductions in the share of drive-alone trips could significantly reduce congestion, emissions, and per-capita VMT. Neither policy (HOV lanes), promotion, or market forces have succeeded in changing vehicle occupancy over the years and many jurisdictions have abandoned efforts to promote carpooling.

<sup>8</sup> Dutzik, Tony and Jeff Inglis, "Millennials in Motion: Changing Travel Habits of Young Americans and the Implications for Public Policy," U.S. PIRG Education Fund Frontier Group (Oct. 2014): 20, [http://www.hsr.ca.gov/docs/Newsroom/reports/2014/Oct\\_2014\\_USPIRGReport\\_101414.pdf](http://www.hsr.ca.gov/docs/Newsroom/reports/2014/Oct_2014_USPIRGReport_101414.pdf)

<sup>9</sup> Zipcar's Annual Millennial survey Shows the Kids are All Right," published January 27, 2014, <http://www.zipcar.com/press/releases/fourth-annual-millennial-survey>

<sup>10</sup> Nancy McGuckin, "Young People's Changing Impact on Travel Demand" (PowerPoint presentation, 10th Annual Travel data User's Forum, 93rd Transportation Research Board).

<sup>11</sup> Cambridge Systems, Inc., "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions," Urban Land Institute (2008): 7, <http://www.fta.dot.gov/documents/MovingCoolerExecSummaryULLI.pdf>.

■ **Vehicle availability.** After the middle of the last century, almost all households had a car, but many had only one. If there were two or three drivers in the household, only one at a time could be driving, limiting the potential for per-capita VMT. Between 1960 and 1980, the number of registered vehicles per licensed driver doubled and by the 1990s, there were more cars than drivers in some states. As one might expect given that one person can't drive more than one car at a time, the number of cars per driver has not increased much in the last 20 years and vehicle availability has not constrained per-capita VMT.

■ **Rebound effect.** In recent discussions of energy and greenhouse gas policies, much has been made of the rebound effect, whereby increases in energy efficiency lead to lower per-unit costs for consumption and higher quantities consumed. In the case of automobile VMT, it is expected that improvements in fuel efficiency lead to higher VMT than would otherwise take place.<sup>12</sup> While the rebound effect is real and expected, its existence does not mean that per-capita VMT will necessarily increase, only that it will be higher than it would be if energy efficiency increased and the rebound effect did not exist. The rebound effect likely has dampened the rate at which per-capita VMT has decreased, relative to what that rate would have been without improvements in efficiency, and it likely will continue to do so.

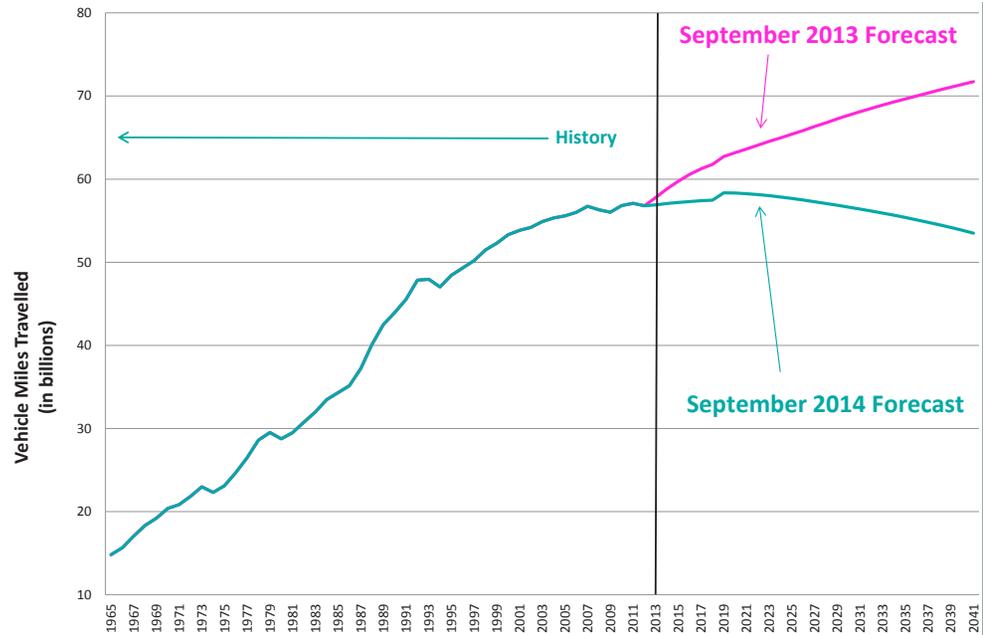
Just looking at what happened to per-capita VMT over the second half of the last century, it is not at all unreasonable to expect that the trend would have to end, having more than doubled since 1970. There has to be a limit to how much vehicle use people will require, regardless of all the factors discussed above.

**WHAT WILL HAPPEN TO VMT IN THE FUTURE?**

Looking at the factors that affect per-capita and total VMT and where each is likely headed, we expect that:

- Population will continue to grow slowly and steadily
- The fuel efficiency of vehicles, like fuel efficiency through out the economy will rise.

**Figure 5: WSDOT VMT Forecast Comparison, 1965-2041**



Source: Washington State Department of Transportation

- Demographic factors will combine to put slight downward pressure on per-capita VMT as baby boomers continue to retire and the millennials, who are less inclined to drive, take over the peak driving years.
- Telecommuting, online shopping, and other ways to substitute technology for travel will continue to grow in prevalence and also will put downward pressure in per-capita VMT
- Land-use policy is likely to continue to promote compact growth and shorter travel distances, especially in Oregon. Increased policy emphasis on greenhouse gas emissions will focus on reductions in fossil fuel consumption, which, if successful, will indirectly reduce per-capita VMT, at least in the near term.
- Improvements to transit service and to infrastructure for active modes likely will continue, reducing the need for and share of auto trips in urban areas, which will continue to put downward pressure on per-capita VMT.

<sup>12</sup>Van Dender, Kurt and Kenneth A. Small, "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect," Department of Economics University of California, Irvine (Aug. 2007): 2, 31, [http://aida.econ.yale.edu/~nordhaus/homepage/documents/small\\_dender\\_rebound.pdf](http://aida.econ.yale.edu/~nordhaus/homepage/documents/small_dender_rebound.pdf).

Per-capita VMT likely will continue to decrease or remain level as population continues to grow, resulting in total VMT near current levels, or perhaps increasing or even decreasing modestly.

### WHERE IS FUEL EFFICIENCY HEADED?

As noted earlier, vehicle miles traveled, miles per gallon, and cents per gallon of tax all determine fuel tax revenue. We concluded that VMT is unlikely to increase much. Now we turn to examining how many gallons are likely to be consumed traveling those miles.

Fuel-tax revenue is determined by the weighted average efficiency of all tax-paying vehicles. In Oregon, tax-paying vehicles include gasoline-powered on-road vehicles and privately-owned, diesel-powered, on-road vehicles that do not pay the weight-mile tax or road use assessment fee. The weighted average fuel efficiency for those vehicles can change as:

- Individual existing vehicles are equipped, loaded, or driven differently.
- Miles are shifted between vehicles that are more and less efficient. This can happen almost instantly in response to changes in fuel prices, but has limited potential for changing overall fuel consumption.
- Individual vehicles are replaced with new vehicles that are more or less efficient. This can result in large changes in fuel consumption per mile in the long run, but it takes time for large numbers of vehicles to change. And since the value of older, less-efficient vehicle decreases with fuel efficiency gains in the rest of the fleet the opportunity cost of vehicle replacement increases, which further slows this process.

The first of these factors is unlikely to have much effect. The second can result in noticeable swings in fuel consumption in response to price changes, but can swing back just as easily and, as noted, has limited potential as almost all of the shifts are between vehicles within the same household.

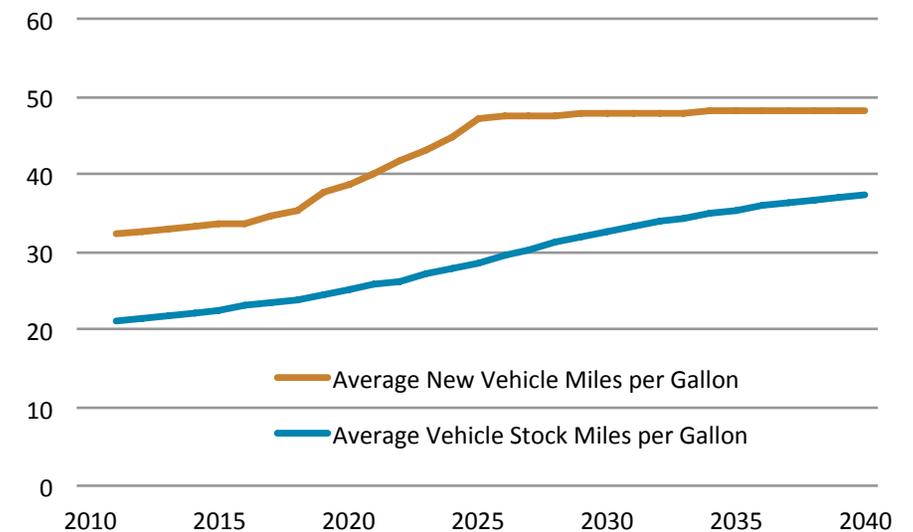
The third factor, fuel consumption by vehicles that have yet to enter the fleet, is the most likely to result in significant, lasting changes in fuel consumption by the fleet. Its effect takes time to be felt, but accumulates and lasts, especially given the longevity of today's vehicles. Technological improvements, encouraged by corporate average fuel economy (CAFE) standards, will increase fuel efficiency within every class of fossil-fueled

vehicle over time. Consumer preferences and fuel prices (including taxes) will determine the mix of vehicles from different classes that are sold and personal income and consumer confidence will affect how many new vehicles are sold.

Issue papers from prior studies have examined likely market penetration for electric and hybrid vehicles and the effect those would have on fuel-tax revenues. They concluded that while a variety of factors might slow the adoption of electric vehicles, adoption will occur and at a pace that accelerates over time. Hybrid vehicles, including plug-in hybrids are now widely understood and accepted in the market and their market share continues to increase. Numerous studies have concluded that in the long run, there will be fewer and fewer gallons to tax for a given amount of travel.<sup>13</sup> There may be disagreement about the expected rate of change, but there is broad consensus about the direction.

The U.S. Department of Energy's Energy Information Administration forecasts energy demand and its constituent elements. The forecasts that are part of the Annual Energy Outlook 2014<sup>14</sup> include sensitivity analysis

**Figure 6: Light-Duty Vehicle Miles per Gallon (Annual Energy Outlook 2014)**



Source: U.S. Department of Energy

<sup>13</sup>Seven Trends that Spell Trouble for Transportation Funding," last modified March 12, 2013, [http://www.oregon.gov/ODOT/GOVREL/Pages/Seven\\_Trends.aspx](http://www.oregon.gov/ODOT/GOVREL/Pages/Seven_Trends.aspx).

<sup>14</sup>[http://www.eia.gov/forecasts/aeo/pdf/0383\(2014\).pdf](http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf)

that examines alternate assumptions about vehicle use and respects the department's predictions concerning vehicle fuel efficiency. The vehicle fuel efficiency projections are included in Figure 6 (on the previous page). Figure 7 displays three scenarios regarding VMT growth over time and Figure 8 displays the resulting energy use for those scenarios.

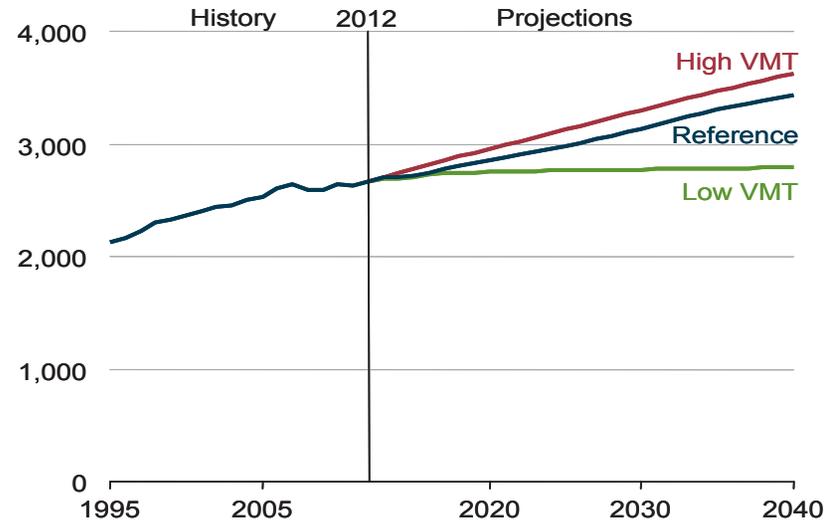
## CONCLUSIONS

The number of taxed gallons of motor fuels (subject to motor fuel or use fuel taxes) in Oregon peaked in 2007. It is possible that will prove to be an all-time record. While population is expected to continue to increase, and per-capita VMT will bounce around with the business cycle, the growth in per-capita VMT that was observed between 1970 and 2000 is over and there is evidence that the trend may be back down at least for a while. Compounding the effect of decreasing per-capita VMT, increasing fuel efficiency is expected to drive down fossil fuel consumption in the long run. While this is welcome news for those working on energy and greenhouse gas policies, it does not bode well for highway finance.

Policymakers in Oregon have responded. The fuel tax rate was increased in 2011 by six cents per gallon (25%), the first increase since 1993. While the increase did not catch up to inflation since 1993 (43%), it did help stabilize revenues. SB 810, passed by the 2013 Legislative Session, authorized a 1.5 cents per mile road usage charge for automobiles and allowed up to 5,000 vehicles to voluntarily participate. There is no termination date for the program and it is expected that if it works out, additional enrollment will be allowed and, will eventually be required for electric and plug-in hybrid vehicles. Alternative long-term approaches to highway finance include so-called "efficient fees" that look to recover highway costs directly from users. Such approaches can be directly tied to investment policies that use these revenues to address capacity deficiencies in transportation supply.

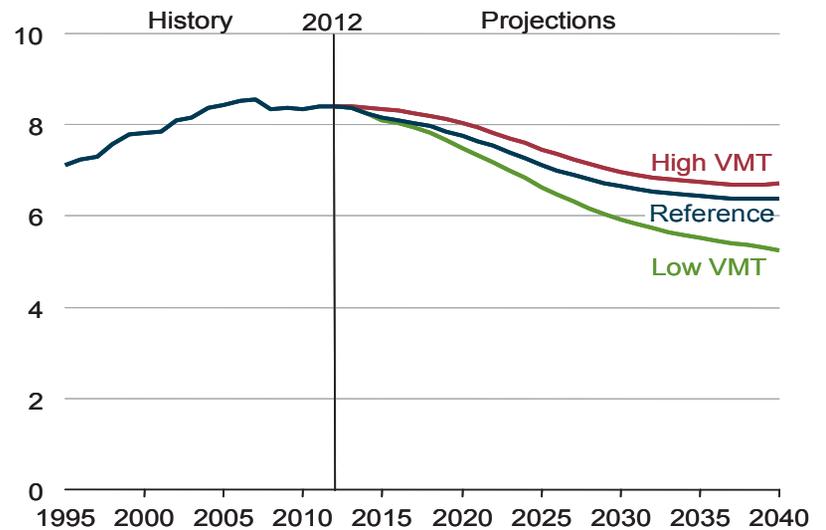
In the shorter term, there is growing consensus among interested parties that another fuel tax increase should be a part of transportation the funding package to be adopted by the 2015 Legislature.

**Figure 7: Total light-duty vehicle mile traveled in three cases, 1995-2040 (billion miles)**



Source: Total light-duty vehicle miles traveled in three cases, 1995-2040.<sup>15</sup>

**Figure 8: U.S. light-duty vehicle energy use in three cases, 1995-2040 (million barrels oil equivalent per day)**



Source: U.S. light-duty vehicle energy use in three cases, 1995-2040.<sup>16</sup>

<sup>15</sup>History: U.S. Department of Transportation, Federal Highway Administration, "Table VM-1," Highway Statistics Series 2011 (March 2013), <https://www.fhwa.dot.gov/policyinformation/statistics/2011/>. Projections: AEO2014 National Energy Modeling System AEO2014 National Energy Modeling System.

<sup>16</sup>History: U.S. Department of Transportation, Federal Highway Administration, National Household Travel Survey, <http://nhts.ornl.gov/download.shtml>. Projections: AEO2014 National Energy Modeling System.

# Appendix B3: Issue Paper

Other State HCASs

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## INTRODUCTION

This document summarizes three highway cost allocation studies (HCAS) published during 2009 to 2013: Nevada 2009, Idaho 2010, and Minnesota 2012. This review of recent HCAS is intended to investigate HCAS processes and methods used in other states, with particular attention paid to innovations, issues, or other methodologies or data that might be of use or interest for the Oregon HCAS process. The document also summarizes the findings from recent papers and reports on HCAS methods.

## SUMMARY

### OVERVIEW OF HCAS STUDIES

#### 2009 Nevada Highway Cost Allocation Study

The Nevada HCAS used the FHWA State HCAS software and methodology, conducted the study using ten vehicle classes (based on the HPMS vehicle classes), and presents equity ratios for vehicle weight using 2,000 lb. increments. The study included revenues from the vehicle sales tax and ad valorem tax for passenger vehicles. As a result, total state revenues were roughly 75% higher than total state expenditures in calculating the unadjusted state equity ratios. Inclusion of revenues that are diverted to non-highway increases the revenue shares for passenger vehicles. Two other unique aspects of the study are the inclusion of deferred maintenance costs for vehicle cost responsibility and the subtraction of federal stimulus funding from deferred maintenance. The study found that heavy vehicle user fees do not increase as fast as heavy vehicle cost responsibility. Light

vehicle classes have equity ratios greater than 1.0 and heavy vehicles have equity ratios less than 1.0.

#### 2010 Idaho Highway Cost Allocation Study

The report considers the equity of Idaho's tax structure for highway users and whether different vehicle classes are paying their proportional share of highway costs. The Idaho HCAS used a refined version of the FHWA State HCAS Model. The model was used to consider how adjustments to the current tax and fee structure and the implementation of a vehicle miles travelled (VMT) fee could affect equity ratios. The study differentiates user classes by vehicle class and weight for a total of 20 user classes. For state and federal programs combined, the study finds that highway user payments fall short of expenditures by 20% (\$139.5 million per year). The study also finds that when collections from state and federal programs are combined, payments from combination trucks fall short of cost responsibility by 33%, whereas payments from automobiles exceed cost responsibility by 47%. At a state level, similar results hold, with combination trucks' payments falling 27% short of cost responsibility and automobiles' payments exceeding cost responsibility by 26%.

#### Minnesota Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees, 2012

The report examines the pros and cons of different highway cost allocation methods to use in Minnesota and presents a methodology that is most appropriate for the conditions in Minnesota. The report first presents the results of using the State HCAS tool developed by the

FHWA. The report then develops and presents the results from a HCAS that was customized for the state, Minnesota Highway Cost Allocation Tool (MHCAT). The report also presents the findings from experiments on auction-based permitting systems.

### OREGON'S HCAS AND DIFFERENCES WITH OTHER STATES

#### Cost-Occasioned Approach and Incremental Method

Oregon, in addition to other states, uses the cost-occasioned approach for its HCAS. The basic idea behind this approach is that each class of road user should pay for the road system in proportion to the costs associated with the road use by that class.

Within the cost occasioned approach, Oregon uses the incremental method. This method divides particular aspects of highway costs into increments. It allocates the costs of successive increments to only the vehicles needing the higher cost increment.

A primary example of the incremental method is with bridge allocation costs. The first increment for a new bridge identifies the cost of building the bridge to support its own weight and other non-load related stresses. This is a common cost responsibility, and allocated across vehicle classes on basis of each user class's share of total VMT. The next increments identify the additional cost of building the bridge to accommodate progressively heavier weight classes of vehicle and the costs are allocated on the basis of relative VMT within a truncated range of vehicle weight classes.

### Oregon's Weight Mile Tax

A key difference between Oregon and other states is that Oregon implements a weight mile tax in addition to a fuel tax. The Federal FHWA HCAS tool does not support a weight mile tax. Oregon has developed its own HCAS tool that supports a weight mile tax. The weight mile tax is structured in terms of 2,000 pound increments.

Oregon's use of a weight mile tax means that it is able to achieve much better equity ratios. Without a weight mile tax, a state would have to rely on high truck registration fees since the fuel tax alone does not recover the damage to roads imposed by heavy trucks. As vehicle weights increase, the damages imposed to roads increases super-linearly, but fuel consumption increases sub-linearly. This means that as vehicle weights increase, the costs they impose on the road are increasingly higher than the amount of fuel taxes they pay. The inclusion of a weight mile tax allows the State to capture the higher costs from heavier vehicle weights.

It is interesting to note that the 2012 Minnesota report examines the hypothetical effects of including a weight-mileage fee where the user pays a usage fee based on vehicle miles traveled and the tax rate per mile is determined by the registered gross weight of the vehicle. Currently, Minnesota charges only a weight fee that is determined by a commercial vehicle's RGW (e.g., a registration fee). The report finds that adjusted equity ratios under both hypothetical weight-mile fee scenarios are closer to the target ratio (one) than the weight fees for most vehicle classes. [Exhibit 2](#) (p. 105)

shows the adjusted ratios at the state level for the weight fees and the weight-mile fees.

### Other Differences

- Oregon uses 2,000 pound increments in its HCAS whereas most other states use 5,000 pound increments. This allows Oregon's HCAS to have a finer grain of analysis than other states.
- Oregon, Nevada, and Idaho use the National Pavement Cost Model (NAPCOM) for pavement costs. However, Oregon has modified NAPCOM to use 2,000 pound increments instead of 5,000 pound increments. The 2012 Minnesota report uses regression coefficients from NAPCOM for Minnesota to allocate pavement repair costs.
- Oregon uses different PCE VMT (regular and congested) allocators depending on the type of cost. For example, the common cost portion of projects that add highway capacity are allocated based on congested PCE VMT. Congested PCE VMT uses the shares of PCE-weighted VMT that are present during the most congested hour of the day on that functional class. Using congested PCE VMT in cases where costs are incurred to add capacity means that a portion of those costs is allocated based on the users that are driving the need for additional capacity.
- Unlike Nevada's 2009 HCAS, Oregon's HCAS does not include deferred maintenance. Oregon has looked at deferred maintenance when determining an efficient fee. However, Oregon does not include deferred maintenance in its HCAS because it

has very well-defined costs that are within the upcoming biennium.

- Oregon includes a studded tire adjustment that takes into account the additional damage that they cause to the roads.
- Oregon uses truncated VMT allocators for different types of costs to allocate those costs to a subset of all vehicles. For example, the collection costs of the motor carrier Transportation Division are allocated on the basis of VMT for vehicles over 26,000 pounds.
- Oregon's adjusted equity ratios reflect adjustments for subsidized vehicles. In contrast, Nevada's adjusted equity ratios do not consider subsidized vehicles and instead are calculated based on share of revenue and cost responsibility share, rather than gross dollar amounts.
- [Exhibit 4](#) (pp. 109-110) provides a high-level overview of different states' HCASs. The table provides information on the states' HCAS methods, key allocators, types of revenue examined, and cost responsibility for heavy vehicles.

### OVERVIEW OF HCAS METHODS

#### Models for Highway Cost Allocation, 2013

The report reviews the traditional HCAS methods (incremental, proportional, or a combination of the two), and then presents an alternative, non-traditional HCAS method that is based on concepts from the theory of cooperative games.

### **A Road Pricing Methodology for Infrastructure Cost Recovery, 2010**

The broad motivating question for the report is: How can governments equitably recover infrastructure costs from truck users based on real-time operations and individual vehicles? The report presents a framework for charging commercial vehicles using weigh-in-motion (WIM) systems.

### **Bridge Structure Comparative Analysis, Comprehensive Truck Size and Weight Limits Study, 2013**

This study provides a list of agencies that provide technical support through research, ongoing studies, and practice. The study provides a list of documents that the study reviewed with short summaries. A number of the documents address the issue of how to recover costs from heavy vehicles in proportion to the damage they cause on bridges.

### **State Highway Cost Allocation Studies: A Synthesis of Highway Practice**

This report is intended to help states with HCAS methods by laying the foundation on current HCAS methods and areas of improvement for HCAS methods. The report reviews the HCAS methods used by different states, the conceptual foundation of HCAS methods, methods for revenue attribution, and arising issues with HCAS methods.

## **HCAS BY OTHER STATES**

### **2009 NEVADA HIGHWAY COST ALLOCATION STUDY**

The 2009 Nevada HCAS used a refined version of the 1997 FHWA State HCAS program (HCASP). The study covers the eight-year time horizon between 2009 and 2016. Ten vehicle classes (auto, bus, and eight single unit or tractor trailer truck classes) are used, based on the twelve HPMS vehicle classes. Equity ratios are tabulated by vehicle class and also by registered vehicle weight (using 2,000 lb. increments).

The 1999 Nevada HCAS adopted many of the recommendations from the 1994 audit of the Nevada HCAS process. Two additional recommendations were adopted in the 2009 HCAS:

- The use of more vehicle classes. Previously only basic and heavy vehicle classes were differentiated for reporting purposes.
- Inclusion of highway user fees that are diverted to non-highway uses (e.g., inclusion of federal highway funds diverted to mass transit and inclusion of state vehicle sales tax and ad-valorem tax revenues which are diverted to general fund).

Nevada calculates unadjusted and adjusted equity ratios. Unlike Oregon, Nevada's adjusted equity ratios do not reflect subsidized vehicles. Rather, Nevada's adjusted equity ratios are calculated based on share of revenue and cost responsibility share, rather than gross dollar amounts.

The primary difference between the equity ratios in the 1999 Nevada HCAS and 2009 Nevada study is the inclusion of revenues from the vehicle sales tax and the ad valorem (government service) tax. Another difference in the 2009 study from previous Nevada DOT studies is the use of the improved NAPCOM model and more accurate weigh-in-motion (WIM) data for operating weights of heavy vehicles.

Nevada DOT data sources were used when available for calculating revenue, determining future VMT, and determining expenditure classifications. The VMT forecast is based on the Nevada DOT VMT forecast and is validated by applying an assumed per-person annual mileage to Nevada's forecasted population growth rate. There is no mention of differentiating VMT growth rates by vehicle class, although there is some discussion of per person mileage in rural versus urban areas of the state.

### **Revenue Attribution**

The Nevada HCAS includes both federal and state revenues, and also includes all revenue sources regardless of their use (e.g., includes highway revenues diverted to non-highway purposes). As a consequence of including the vehicle sales tax and ad valorem tax, state revenues are forecast to exceed state highway expenditures by 75%. The study notes that this difference is "counterbalanced" by local expenditures, which exceed local user payments (since the state and local governments direct a portion of general funds to local roadways).

### Cost Responsibility

Assignment of expenditures to work categories is based on previous expenditures, funded projects data (e.g., STIP, etc.), and trends in project expenditures. In addition to funded future expenditures, the Nevada HCAS also includes estimates of deferred pavement and bridge preservation for allocation of system preservation costs. Nine project work types, covering the typical project categories for pavement, bridges, maintenance, preservation, etc., were used to classify highway expenditures.

Nevada received \$201 million in federal stimulus funding, of which \$130 million is deducted from the backlog of preservation and the remaining (\$71 million) is applied to projects along the National Highway System and urban projects in the STIP. The forecast of future expenditures was developed using recent trends in expenditures and anticipated revenues and consultation with NDOT. Projects were assigned work types based on recent year expenditures and programmed expenditures in the STIP. The FHWA State HCAS Model was used to estimate cost responsibility by vehicle class using the categorized expenditures and allocators for each type of expenditure. Cost allocation by work type is summarized based on the information in the HCAS report:

- Pavement cost responsibility is determined using NAPCOM and vehicle class weight distributions developed from weigh-in-motion data. New bridge construction costs were allocated based on an incremental method, as applied in the FHWA HCASP model.

- Bridge replacement costs were allocated based on the replacement attributed to deficient load-bearing capacities relative to total degradation using the FHWA Bridge Sufficiency Rating formula.
- Bridge rehabilitation costs were apportioned based on determining the share of load-related costs relative to all costs based on a sample of bridge repair projects and default values from the FHWA's Bridge Needs and Investment Process.
- DMV expenditures related to the Motor Carrier Program were allocated to heavy vehicles, based on heavy vehicle VMT. The remaining DMV expenditures are allocated across all vehicle classes, based on shares of travel.
- Department of Public Safety expenditures include the State Emergency Response Commission (SERC), which responds to highway incidents. Heavy vehicles are allocated half of the SERC costs, based on the rationale that heavy vehicle crashes are more severe and require more time and expense to clear. The remaining DPS expenditures are allocated based on shares of travel.
- Administrative and overhead costs are allocated to vehicle classes in the same proportion as the sum of the capital and maintenance programs.
- Bond expenditures, both capital expenditures and debt service, are allocated in the same proportion as capital expenditures on urban interstate systems where the bond-financed projects are located.

### Equity Ratios and Findings

The study results are presented as unadjusted and adjusted equity ratios for each vehicle class and by registered gross vehicle weight. Unadjusted equity ratios are constructed as the ratio of gross (dollar amounts) revenues to expenditures from each vehicle class. Adjusted equity ratios are constructed as the ratio of the vehicle class share of revenues to share of expenditures.

As a result of the inclusion of the state vehicle sales tax and ad valorem taxes, state revenues exceed state expenditures. This results in an “overpayment” of highway revenues compared to expenditures and produces a total unadjusted equity ratio for state-only revenues and expenditures of 1.75, reflecting that state revenues exceed state expenditures by 75%.

The effect of including revenues used for non-highway purposes is partially obscured by the inclusion of deferred maintenance and the subtraction of federal stimulus dollars from those deferred preservation expenditures. Excluding vehicle sales tax and ad valorem tax revenues from the total state revenues increases the adjusted heavy vehicle class share of state revenues to 31.1% from 18.9%. The heavy vehicle adjusted equity ratio goes from 0.42 up to 0.74 (state revenues and expenditures only) when these non-highway revenues are excluded.

The findings from the study suggest that Nevada’s heavy vehicle fee structure does not increase proportionally with registered weight; hence heavy vehicles tend to underpay. Only vehicles less than 8,000 lbs. have an adjusted equity ratio of 1.50. This is consistent with the findings from other states’ HCAS.

## 2010 IDAHO HIGHWAY COST ALLOCATION STUDY

The report considers the equity of Idaho's tax structure for highway users and whether different vehicle classes are paying their proportional share of highway costs. The 2010 Idaho HCAS used a refined version of the FHWA State Highway Cost Allocation Tool (HCAT). The HCAT was used to consider how adjustments to the current tax and fee structure and the implementation of a vehicle miles travelled (VMT) fee could affect equity ratios.

Two factors affecting the 2010 Idaho HCAS include the repeal of the weight-distance tax in favor of a mileage-based registration fee system and the types of projects that are funded by the Grant Anticipation Revenue Vehicle (GARVEE) bonds influence the equity ratios in the report. Idaho issued GARVEE bonds that are backed by federal aid to advance its construction program. The GARVEE bond program affects the cost allocation, as a higher portion of expenditures are pavement-related, which in turn affects the cost responsibility for heavy trucks. Under the reduced GARVEE scenario, expenditures are equal to the annual debt service payments during the six-year time period.

The study uses 20 vehicle classes. Vehicle classes are differentiated by vehicle type and weight. The study has a six-year time period from 2007 to 2012. The study considers three levels of government: state, federal, and local expenditures and revenues. Travel and expenditure data are broken down by rural and urban highway functional classes. Rural includes interstate, principal arterials, minor arterials, major collectors, minor collectors

and local. Urban includes interstate, principal arterials, minor arterials, collectors and local. Travel data includes total vehicle miles traveled by the 20 vehicle classes and 11 functional road classifications.

Key findings from the Idaho HCAS include:

- Highway user payments fall short of expenditures by 20% (\$139.5 million per year) for state and federal programs combined.
- With state and federal programs combined, combination trucks' payments fall 33% short of cost responsibility (28% under reduced GARVEE scenario), whereas automobiles' payments exceed cost responsibility by 47% (38% under reduced GARVEE scenario).
- Considering state programs alone, combination trucks' payments fall 27% short of cost responsibility (14% under reduced GARVEE scenario), whereas automobiles' payments exceed cost responsibility by 26% (8% under reduced GARVEE scenario).

### Revenue Attribution

Revenue data include state and federal historical data from 2007 to 2009 and revenue forecasts based on Idaho Transportation Department (ITD) forecasts from 2010 to 2012. Revenue data include receipts from highway users from the tax and fee structure (e.g., registration fees, motor fuel taxes, driver's license fees, permit fees, and title fees).

The study obtained federal revenues that are attributable to highway users in Idaho for 2008 and 2009 from FHWA 2009 Highway Statistics. The FHWA estimates were forecast forward until

2012 using the revenue forecasts prepared by ITD. The federal tax revenue estimates reflect what Idahoans pay into the Federal Highway Trust Fund.

The study attributed revenue to the 20 vehicle classes and to registered gross weight classes in 2,000 lb. increments above 8,000 lbs. Some of the default data estimates in the FHWA HCAT were replaced with Idaho-specific inputs. The study worked with the ITD and other data sources to estimate the following characteristics for each vehicle class: VMT, percentage of VMT outside of Idaho, MPG, and number of registered vehicles. This allowed tax revenue to be attributed to each vehicle class. Fuel tax revenues were attributed by vehicle class based on the VMT estimates and the vehicle class's MPG. Revenues from registration fees were attributed based on the breakdown of fees by vehicle class (passenger vehicles, trucks, and buses). The study also estimated the number of full fee equivalent vehicles by registered weight class based on total VMT and the average VMT per vehicle estimates.

### Cost Responsibility

The study uses expenditure data for nine categories: new pavements, rehabilitated pavements, new bridge, replacement bridge, repair bridge, grading, other construction, maintenance, and administration and other expenditures. Expenditure data were obtained for capital expenditures from ITD for the 2007-2012 time period.

The study estimated cost responsibility for each vehicle class using the FHWA HCAT. Idaho updated the FHWA HCAT to reflect Idaho's

highway system and vehicle use. The study used weigh-in-motion (WIM) data to refine weight-related HCAT model inputs. The study used a recent FHWA run of the National Pavement Cost Model (NAPCOM) with 2007 highway section data from ITD. The study uses bridge cost allocation procedures developed by the FHWA in the Federal HCASs in 1982 and 1997.

### Travel Data

The study derived VMT data by functional road class and by vehicle class using vehicle classification data from 2004-2008, breakdowns of VMT by functional class from 2008 and 2009, and weigh-in-motion (WIM) data from 2008 and 2009 from ITD. The Idaho Highway Performance Monitoring System (HPMS) has 12 vehicle classes but the FHWA HCAT uses 20 vehicle classes. Idaho used the two years of WIM data to map the 12 HPMS vehicles classes estimated from the classification count data into the 20 vehicle classes. WIM data were only provided for three functional classes: rural interstate, rural principal arterial, and rural minor arterial. The study had to make further assumptions on how to apply the vehicle splits to other roads.

### Equity Ratios and Findings

The Idaho HCAS reports the unadjusted and adjusted equity ratios for the state level as well as the state and federal levels combined. Similar to HCAS in other states, as registered gross weights increase, equity ratios decrease.

One particularity of the Idaho HCAS is the GARVEE bond program. The GARVEE bond program affects the cost allocation, in that a much higher proportion of highway funds are directed toward pavement expenditures. Since

most pavement costs are a result of the impact of heavy trucks, the bond program significantly increases the cost responsibility to heavy trucks (in particular, trucks with 12,000-18,000 lbs. per axle or 28,000-34,000 lbs. per pair of axles).

The researchers performed a sensitivity analysis to explore the effects of the GARVEE program on the HCAS findings. The researchers considered the scenario where expenditures are equal to the annual debt service payments during the 2007-2012 time period. The annual debt service payments over the six years are approximately equal to 26% of the GARVEE bond expenditures over the same time period. In the reduced GARVEE bond scenario, construction expenditures decrease by \$96.9 million. Under this scenario, adjusted equity ratios increase for combination trucks and decrease for automobiles. On the state level, there is a greater difference in results between the two scenarios than on the level where state and federal are combined. On the state level, the adjusted equity ratio for automobiles drops from 1.26 to 1.08 under the reduced GARVEE scenario and increases for combination trucks from 0.73 to 0.86.

The other notable change for Idaho was the repeal of the weight-distance tax on trucks in favor of a mileage-based registration fee system in 2001. According to the study, if the weight-distance tax had remained in place, revenues were forecast to increase to \$60.4 million in 2008 (based on analysis of historical trends). Instead, under the mileage-based registration fee system, revenues were \$48.8 million in 2008 (\$11.6 million lower than the forecasts under the weight-distance tax).

### Policy Analysis

The Gubernatorial Task Force on Modernizing Transportation Funding evaluated 19 possible sources of revenue. They considered eight criteria in their evaluation: fairness, public acceptance, revenue predictability, trend (up or down), cost-effectiveness of implementation, readiness, competitiveness, and out-of-state equity. The top ten revenue sources are (from highest to lowest): fuel tax of 5 cents per gallon, fuel sales tax, index fuel tax, state truck registration fee, index passenger vehicle registration fee, county vehicle registration fee, sales tax on auto sales, parts, tires and accessories, weight distance tax, electric vehicles, and alternative fuels tax.

The study examines the equity impacts from seven different policy options. The seven policy options are listed below along with their outcomes on equity (equity ratios are for the state and federal levels combined):

1. *Gasoline and special fuel tax rates increase by 5 cents per gallon.* Revenues forecast to increase by \$46.2 million annually. Tax falls on passenger vehicles and trucks equally, and there is little change in adjusted equity ratios.
2. *Gasoline tax rate increases by 5 cents per gallon.* Adjust the special fuel tax rate such that the equity ratio for vehicles with RGWs of over 26,000 lbs. is equal to one. Revenues forecast to increase by \$307.6 million annually. Equity ratios improve across vehicle classes (move closer to one). Adjusted equity ratios for automobiles and DS8+ change from 1.47 to 1.06 and 0.49 to 0.67, respectively.

3. *Special fuel tax rate increases by 5 cents per gallon, and gasoline tax rate adjusts to the level needed to achieve equity.* Revenues forecast to decrease by \$147.0 million annually. Equity is almost realized between broad vehicle classes (between vehicles above and below 26,000 lbs.).

4. *All vehicle registration fees increase by 10%.* Revenues forecast to increase by \$11.6 million annually. Fees are applied to all vehicle classes, and have almost no effect on equity.

5. *Passenger car vehicle registration fees increase by 10% and heavy truck registration fees increase by level needed to achieve equity.* Revenues forecast to increase by \$165.8 million annually. Heavy truck registration fees would need to increase by a factor of 4.07 to achieve equity. Equity would be achieved between light and heavy vehicle classes. However, payments from heaviest vehicle classes would still fall short of cost responsibility by up to 45%.

6. *Heavy truck registration fees increase by 10% and passenger car vehicle registration fees increase by level needed to achieve equity.* Revenues forecast to decrease by \$47.7 million annually. Passenger car (light vehicle) registration fees would be eliminated. Equity would improve with the automobiles adjusted equity ratios decreasing from 1.47 to 1.38.

7. *Vehicles over 26,000 lbs. RGW pay a VMT tax.* Revenues forecast to increase by \$81.9 million annually. VMT fees are around 5.3 cents per mile for vehicles with RGW of 80,000 lbs. and 11.1 cents per mile for RGW

of 105,500 lbs. Equity ratios for heavy vehicles improve significantly. The adjusted equity ratio for the DS8+ vehicle class would increase from 0.49 to 0.85. For the LT4 vehicle class, the adjusted equity ratio would decrease from 1.18 to 1.03.

**2012 MINNESOTA HIGHWAY COST ALLOCATION AND DETERMINATION OF HEAVY FREIGHT TRUCK PERMIT FEES**

Minnesota conducted an HCAS in 2009 that used the FHWA's State Highway Cost Allocation Tool (HCAT), relying on some national default data and state specific data when it was available. In 2012, the Minnesota Department of Transportation (MnDOT) and the University of Minnesota developed a customized highway cost allocation tool for Minnesota based on the FHWA's tool, and compared the results of the customized tool to the results from the general tool. The report also presents the findings from the HCAS using the FHWA HCAT that are using the same methods as the 2009 HCAS (see 2009 Minnesota HCAS summary at the end of the paper after References).

In the 2012 HCAS, Minnesota compares the results from the FHWA HCAT and a customized tool for MnDOT, Minnesota Highway Cost Allocation Tool (MHCAT). MHCAT fixes known bugs in the FHWA HCAT and is intended to work with Minnesota-specific data. The FHWA HCAT does not allow certain tax revenues (e.g., registration and weight fees) to be attributed to a specific subset of vehicle classes. Additionally, the FHWA HCAT does not correctly allocate administrative costs associated with the collection of registration and

weight fees. Another issue the study found was that the registered gross weight breakdowns for the vehicle configurations are based on representative data from 2001. Furthermore, the mapping of the 12-vehicle configurations to the 20-vehicle configurations is based on national VMT data from 1997.

MHCAT classifies vehicles according to Highway Performance Monitoring System, (HPMS) 12-class whereas FHWA HCAT classifies them according to HCA 20-class. Without a customized tool, use of the FHWA HCAT requires mapping the HPMS classification onto the HCA classification (as in the case of the 2010 Idaho HCAS and the previous 2009 Minnesota HCAS). The customized tool removes unnecessary data manipulation and increases accuracy. MHCAT also allows the user to enter up to eight customized vehicle classes. This is a useful tool for research purposes, such as considering specific changes to tax rules and cost allocation for specific vehicle classes.

The FHWA HCAT cannot allocate external costs such as environmental impacts, congestion, and accident costs. External costs are a result of highway use, and can be significant. However, they are difficult to include into the HCAT since they are dependent on the time of travel and route selected, and they do not depend solely on the type of vehicle and VMT. This is not an issue that is resolved in the MHCAT.

The report also evaluates the HCAS methods, with particular emphasis on tax equity (vertical and horizontal) and efficiency. In particular, the report compares a fuel versus a weight-distance tax using a stylized mathematical model.

The results support that a weight-distance tax or other mileage-based tax that can be differentiated by truck class can help achieve a more equitable tax policy than a universal fuel tax. However, the examples presented also indicate that equity can be improved if the universal tax encourages the truck industry to use trucks that cause less damage. The alternative is to achieve equity through a tax policy that differentiates by truck class and truck usage.

The report lists two categories with two options in each category as directions for future research that are associated with the equity and efficiency of the road-use tax structure.

- **Mileage-Based Taxation:** This can be implemented using a comprehensive *Electronic Road Pricing System (ERPS)* or a *weight-distance tax system*.
  - With an ERPS, tax rates can be set based on vehicle type, vehicle weights, number of axles, congestion levels, and the road conditions for the individual trip.
  - *Weight-distance* taxes are charged based on the vehicle's registration weight, distance travelled, and axle configuration.
- **Special Permits and Willingness-to-Pay:** The state currently issues special permits to oversized or overloaded trucks, but there is a need for a better pricing mechanism. Options to improve the pricing mechanism include:
  - Estimating *Willingness-to-Pay (WTP)* using contingent valuation.
    - Implementing an *auction-based permitting system (ABPS)*.

Minnesota Department of Transportation (MnDOT) provided revenue and expenditure data and traffic data for the 2003-2007 time period. MHCAT, like HCAT, requires pavement parameters, bridge parameters, and vehicles' features and travel-related data. The inputs are in nine different Excel tabs in the MHCAT workbook. Default bridge parameters are imported from HCAT but can be modified to reflect the state's conditions through assistance from the state engineer. The report uses VMT numbers from MnDOT that represent an average from 2004 to 2007.

The workbook requires registered gross weight distributions by vehicle class by 2,000 lb. increments from 8,000 lbs. to 152,000 lbs. These data were obtained from the Vehicle Inventory and Use Survey from 2002 (VIUS 2002) collected by the U.S. Census Bureau. The default data for MPG by vehicle class and RGW, the average annual distance travelled by vehicle class, and the distribution of vehicles by fuel type are all from VIUS 2002. Axle weight distribution data are from WIM systems from 2006.

### Revenue

The MHCAT includes both federal and state revenues. At the federal level, inputs include fuel taxes, heavy vehicle use tax, vehicle sales taxes, and tire taxes. At the state level, inputs include fuel taxes, weight fees (only applicable to trucks), registration fees (passenger vehicles and light trucks), vehicle sales taxes, and permit fees.

### Expenditures

MHCAT inputs related to expenditures are categorized into six parts: state level construction and maintenance, state level

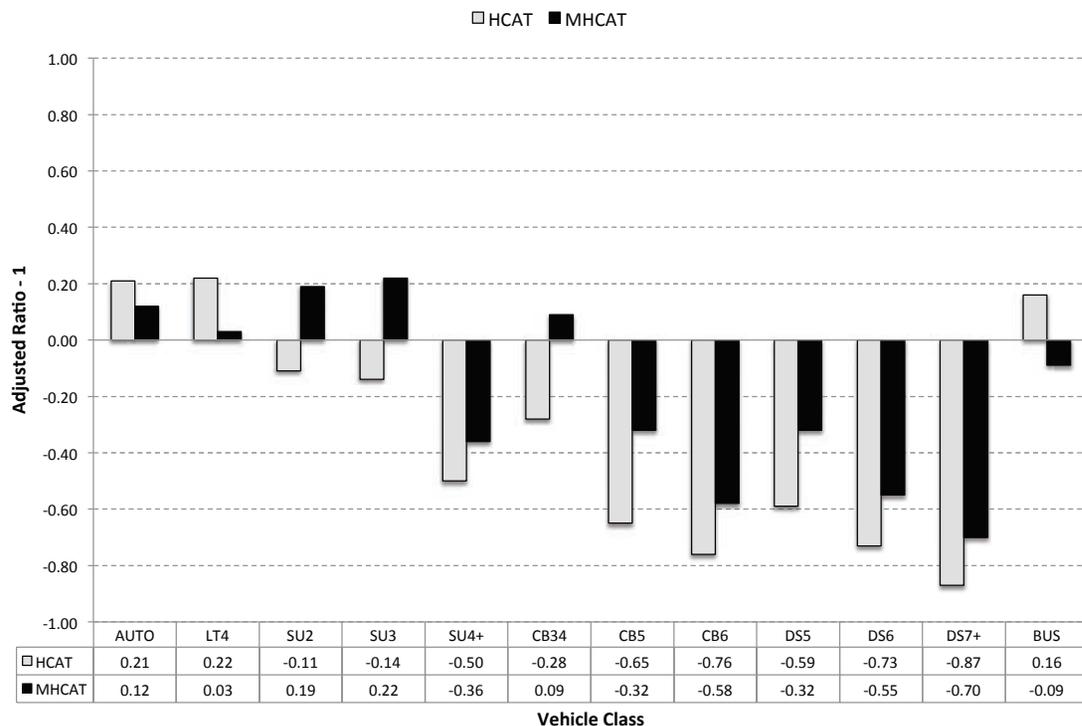
administration, state-aid administration, state-aid construction and maintenance, federal-aid administration, and federal-aid construction and maintenance. Each part requires expenditures disaggregated by highway functional class for 25 categories. The categories include typical highway project categories such as pavement (new, repair, etc.), bridge (new, replacement, rehabilitation), and maintenance and administrative categories. MHCAT includes the costs of collecting user fees on fuel, which are assumed to be zero by many states.

The default inputs on how non-load-related expenditures are allocated are based on FHWA HCAT. These include grading, residual allocators, other costs, and systemwide and DMV costs. The user can specify the percentage of grading costs by vehicle weight. For residual allocators, other costs that are distributed by highway functional class, and systemwide costs and DMV administration costs, the user can specify VMT or PCE-VMT, or a fraction between 0 and 1 (e.g., 0.3 means that 30% is allocated based on VMT and 70% is allocated based on PCE-VMT).

### Equity Ratios and Findings

The report compares the equity ratios obtained from FHWA HCAT and MHCAT. It considers the difference between the adjusted equity ratios from the two tools to the target ratio (one). Like the 2009 Nevada HCAS, unadjusted equity ratios are constructed as the ratio of gross (dollar amounts) revenues to expenditures from each vehicle class. Adjusted equity ratios are constructed as the ratio of the vehicle class share of revenues to share of expenditures.

**Exhibit 1. HCAT (FHWA) and MHCAT: Adjusted Ratios minus Target Ratio (one), State Revenue and Expenditures Only**



Source: Minnesota HCAS 2012, Figure 4.1, p. 52.

In general, the equity ratios from MHCAT are less extreme than those from FHWA HCAT. Exhibit 1 shows the differences between the ratios for FHWA HCAT and MHCAT by vehicle class. The report attributes some of the differences to the fact that RGW, OGW, and axle distributions are based on Minnesota specific data in MHCAT, as opposed to national averages in the FHWA HCAT.

The report finds that automobiles, light trucks, and single-unit trucks (three axles or less) have equity ratios greater than one. The report also finds that all combination trucks (except for

single trailer with four or fewer axles) have adjusted equity ratios less than one. As is the case in other states' HCASs, the study indicates that heavy trucks are not paying taxes in proportion to the damage they cause to road infrastructure.

**Effects of a Weight-Mileage Fee**

Currently, Minnesota charges a weight fee that is determined based on a commercial vehicle's RGW (e.g., a registration fee). The report examines the effects of including a weight-mileage fee where the user pays a usage fee based on vehicle miles traveled and the tax rate

**Exhibit 2. Adjusted Equity Ratios for Weight Fees (RGW registration fee) and Weight-Mile Fees, State**

VC	Weight Fees	W-M Fees (Scenario 1)	W-M Fees (Scenario 2)
AUTO	1.12	1.12	1.08
LT4	1.03	1.03	1.00
SU2	1.19	0.89	0.86
SU3	1.22	0.89	1.00
SU4+	0.64	0.67	0.80
CB34	1.09	0.95	1.07
CB5	0.68	0.75	0.88
CB6+	0.42	0.57	0.71
DS5	0.68	0.81	0.93
DS6	0.45	0.63	0.77
DS7	0.30	0.52	0.67
BUS	0.91	0.91	0.88

Source: Minnesota HCAS 2012, Table 4.15, p. 56.

per mile is determined by the registered gross weight of the vehicle. The report considers two scenarios. The first scenario assumes that total revenues from trucks are not changed (Minnesota collects \$98 million from the weight-mileage fee). The second scenario assumes that the state collects \$160 million from the weight-mileage fee (the amount of load-related expenditures (pavement and bridge) allocated to trucks). The study estimates the cost per mile for each vehicle-RGW class and then sets the tax rate to be proportional to the estimated cost.

Exhibit 2 shows the adjusted ratios at the state level for the weight fees and the weight-mile fees under both scenarios. As the table illustrates, adjusted equity ratios under both weight-mile fee scenarios are closer to the target ratio (one) than the weight fees for most vehicle classes.

### **Auction-Based Permit System (ABPS)**

This section discusses the development and testing of an ABPS that a state transportation agency could implement to learn the demand for permits and freight companies' willingness-to-pay for the permits. The researchers considered multi-item auctions and picked three mechanisms: Vickrey auction with reserve price, Ascending clock auction, and Clinched ascending clock auction. These three mechanisms were picked because they satisfied the following criteria:

- The price paid by a winning bid depends only on the opposing participants' bids.
- Bidders do not gain from over-bidding or under-bidding their true demand.
- The objective of the auction mechanism is to maximize revenue per permit sold.

The report explores the three auction mechanisms and how utility maximizing freight companies would bid under a competitive Nash equilibrium for each mechanism. The researchers then designed an experiment to test the different mechanisms using University of Minnesota graduate students and MnDOT staff members. The results of the experiment indicate that the ascending clock mechanism provided the maximum revenue per permit sold. Issues of auction fairness were not discussed in the report. The report considers the outcome of an auction as efficient when the individual item is sold to the bidder with the highest valuation for the item.

## **HCAS METHODS**

### **A ROAD PRICING METHODOLOGY FOR INFRASTRUCTURE COST RECOVERY, 2010 (BY CONWAY & WALTON)**

The broad motivating question for the report is, "What future method of truck user charging can be employed to equitably recover infrastructure costs from individual vehicles based on real-time operations?" (Conway & Walton, 2010, p. 3). The report presents a framework for charging commercial vehicles using weigh-in-motion (WIM) systems. The WIM systems collect real-time vehicle weight and configuration information that

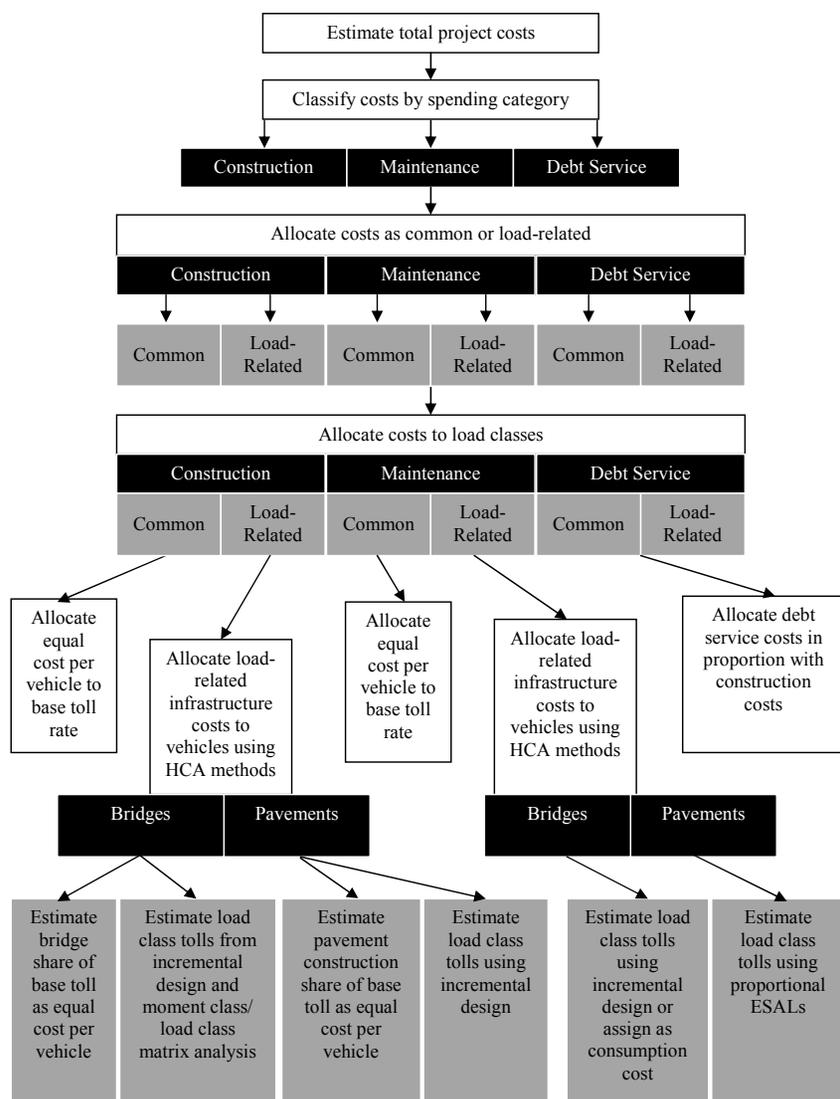
can be used to charge vehicles on a toll structure. The report proposes using highway cost allocation methods to estimate a more equitable toll structure based on the individual axle weights that can be measured real-time using the WIM systems. The report presents a hypothetical case study using information from Texas State Highway 130 to consider the improvements in equity that could be realized using the proposed methodology.

The study proposes a two-part toll. The first part is a base toll that is charged to all commercial and passenger vehicles that is calculated such that all common costs and basic infrastructure costs are recovered. The second part is an additional toll for heavy vehicles that is estimated using the "axle-load" estimation (preferred) or the "number-of-axle" estimation. [Exhibit 3](#) (on the following page) illustrates the process.

Under an axle-load toll structure, heavy vehicles pay an additional cost per axle-load to recover infrastructure costs (pavement and bridge costs) that are required in order to support their weight. Pavement impacts are estimated as a function of individual axle loads, so initial load classes must be developed using the relative impacts on pavement by loads from individual classes. The particular characteristics of the facility with respect to traffic volumes, truck profiles, and axle load distribution need to be identified to determine the relative impacts of each class. Traffic analysis provides vehicle volumes, and WIM data can provide axle load distributions and truck profile information. This information can be used to calculate the probability that a load belongs to a given class and estimate the toll rates for each individual load class.

The case study considers State Highway 130 in Texas. The results indicate that the "axle-load" tolling structure recovers costs more equitably for heavy vehicle consumption than a "number-of-axle (n-1)" structure. The addition of an axle can lessen the load at a given point, reducing the pavement and bridge impacts. The pavement impact is lower from a 20,000 lb. load split across two axles than the same load on one axle. The "axle-load" structure is more effective at mirroring the estimated cost responsibility of different vehicle classes.

**Exhibit 3. Center for Transportation Research/Southwest Region University Transportation Center - Cost Allocation Method for Toll Rate Determination**



Source: Conway & Walton, 2010, Figure 9, p. 90.

**MODELS FOR HIGHWAY COST ALLOCATION, 2013 (BY GARCIA-DIAZ & LEE)**

The report reviews the traditional HCAS methods, incremental or proportional (or a combination of the two) and then presents an alternative, non-traditional HCAS method that is based on concepts from the theory of cooperative games. The study considers how well different HCAS methods fulfill three fundamental properties: completeness, rationality, and marginality. Completeness means that highway costs are fully recovered by all participating vehicle classes. Rationality means that each vehicle class will have a lower cost by participating in the large group of all vehicle classes. Marginality means that each vehicle class pays the incremental cost that is incurred by including it in the grand coalition. Traditional HCAS methods, incremental and proportional, satisfy completeness. The incremental method sometimes satisfies marginality.

The non-traditional method presented in the paper, the Generalized Method (known as the Nucleolus Method in game theory) is based on concepts from the theory of cooperative games. Villarreal and Garcia-Diaz (1985) first proposed the use of this method in HCAS.<sup>1</sup> With this method, all three properties are forcibly satisfied as a result of constraints in the method's mathematical formulation. The generalized method guarantees "that every vehicle class will be allocated a lower cost in the grand coalition (all vehicle classes), as compared to any other smaller coalition (one with fewer vehicle classes than the grand coalition)" (Garcia-Diaz & Lee, 2013, p. 137).

The average marginal cost for a vehicle class, considering all the permutations of vehicles in the grand coalition, is the Shapley Value. The Shapley Value represents the average marginal cost contribution that each vehicle class would make to the grand coalition if it were forming one vehicle class at a time (Garcia-Diaz & Lee, 2013, p. 138). The Aumann-Shapley Value considers two types of costs, the sum of which is the total cost allocated to a vehicle class. The first cost is for ESALs (pavement thickness) and the second is for highway lanes (traffic capacity). The method calculates a cost per ESAL and a cost per lane. This procedure has a number of advantages and tackles some obstacles often found in traditional HCAS. It "allows the consideration of the number of lanes as being a variable and

<sup>1</sup> A Development and Application of New Highway Cost Allocation Procedures. Villarreal-Cavazos A, Garcia-Diaz Transportation Research Record 1009: 34-41. 1985.

depending on the composition of the traffic using a highway (Garcia-Diaz & Lee, 2013, p. 138). This “addresses how seemingly conflicting objectives: lighter vehicles require less pavement thickness and more lanes while heavy vehicles require fewer lanes but thicker pavements” (Garcia-Diaz & Lee, 2013, p. 138). After calculating a cost per ESAL and a cost per lane, the method uses the Shapley Value to allocate the number of available lanes between vehicle classes. The paper provides examples using three vehicle classes.

The paper states that the Generalized Method distributes traffic-related costs more equitably than any other HCAS method, as it considers traffic loads and traffic capacity. The combination of the Aumann-Shapley Value (average cost per ESAL and average cost per lane) and the Shapley Value (used to allocate the total number of lanes among vehicle classes), allows for the possibility to calculate the cost per mile for each vehicle class. The paper also proposes a method for separating bridge construction and traffic capacity costs that is similar to the method for separating pavement thickness and traffic capacity costs. There is the additional step that allocates the traffic-load cost to each weight group in a vehicle class using the incremental method. The paper provides examples using three vehicle classes and four weight intervals.

**BRIDGE STRUCTURE COMPARATIVE ANALYSIS, COMPREHENSIVE TRUCK SIZE AND WEIGHT LIMITS STUDY, 2013**

This study provides a list of agencies that provide technical support through research, ongoing studies, and practice. This list includes national programs such as the Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP) and Strategic Highway Research Program, (SHRP 2). It also includes federal and state transportation agencies and universities.

The second section of the study provides a list of documents that the study reviewed with a link to the document, a summary of the findings, and a discussion of the document’s relevance to one of the Comprehensive Truck Size and Weight (CTSW) Study topics. A key discussion area is how to recover the relatively high structural and infrastructure costs on bridges from heavy trucks. The study examines resources in the literature from 1997 to 2013 that may inform approaches that may help recover these costs more equitably.

**STATE HIGHWAY COST ALLOCATION STUDIES: A SYNTHESIS OF HIGHWAY PRACTICE, 2008 (BY BALDUCCI & STOWERS)**

This report is intended to help states with HCAS methods by laying the foundation on current HCAS methods and areas of improvement for HCAS methods. The report reviews the HCAS methods used by different states, the conceptual foundation of HCAS methods, methods for revenue attribution, and arising issues with HCAS methods.

Since the 1997 Federal HCAS, there have not been many major changes in HCAS practice. A significant development in the past few years was FHWA’s completion of the development and refinement of the National Pavement Cost Model (NAPCOM) and its development of NAPCOM into a model that can be used in state level HCAS. The FHWA also developed generalized state level HCAS software and documentation for the software.

[Exhibit 4](#) summarizes recent state HCASs. Much of the data in the table is from a previous study by ECONorthwest in 2005, but has been updated through 2008 by the research team. The results in the method column indicate that the Incremental and Federal Methods are most commonly used for state HCASs. These fall under the cost-occasioned approach that determines cost responsibility using the costs imposed on the highway by the highway-user class and not just by relative use. A key issue in HCAS is the cost responsibility of heavy-truck vehicle classes. Studies consistently find that heavy trucks payments do not fully cover their cost responsibility.

**Exhibit 4. State Highway Cost Allocation Studies**

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Arizona	1993, 1999, 2000, 2001, 2002, 2005	Federal	31.4% (1999)	VMT, Axle-Load, Gross Weight	State, Federal, and Local Funds Combined
Arkansas	1978	Incremental/Cost Function			
California	1987, 1997	Federal and Incremental	18.90%	ESALs	State, Federal, and Local Funds Analyzed Separately
Colorado	1981, 1988	Federal	37%	VMT, Truck-VMT, ESALs, Ton-Miles	
Delaware	1992, 1993	Federal and Incremental	20.33%	VMT, ESALs, PCE, Axle-Miles, Registrations	State and Federal Funds Combined Only
Florida	1979	Incremental	64.50%	VMT, ESALs, Axle-Miles, Registrations	State and Federal
Georgia	1979, 1982	Incremental	51.2% (1979)	VMT, ESALs, GVW, AMT	State and Federal
Idaho	1987, 1994, 2002, 2010	Prospective Cost-Occasioned, Modified Federal, NAPCOM	Federal & State: 43.5% or 40.9%* State: 40.6% or 34.1%*	VMT, ESALs, ADT	State, Federal, and Local Funds Combined
Indiana	1984, 1988, 1989, 2000	Incremental/Consumption	53.20%	ESALs	State, Federal, and Local
Iowa	1983, 1984	Federal	48.94%	VMT, ESALs, Ton-Miles, AMT, PCE	
Kansas	1978, 1985	Hybrid	41.85%	VMT, ESALs, PCE, AMT, Ton-Miles, Number of Vehicles	State Funds
Kentucky	1992, 1994, 1996, 1998, 2000	Federal	54.92%	VMT, ESAL-VMT, PCE, Axle-Miles	State and Federal Funds Combined
Maine	1956, 1961, 1982, 1989	Hybrid/Expenditure Allocation	35.60%	VMT, ESALs, PCE, Delphi, TMT, Standard Vehicle Equivalent	State and Federal funds
Maryland	1989, 2009	Federal	33.30%		State and Local Funds
Minnesota	1990 2009, 2012	Federal and Incremental, Modified Federal	Federal & State: 29.47%	VMT, ESALs, ADT	State and Federal Funds Combined and State
Mississippi	1980	Incremental	36%	VMT, Truck-VMT	

**Exhibit 4 (continued). State Highway Cost Allocation Studies**

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Missouri	1984, 1987, 1990	Federal		VMT, Vehicle Size, Vehicle Weight	
Montana	1992, 1999	Federal	33%	VMT, ESALs, AMT	
Nevada	1984, 1985, 1988, 1990, 1992, 1994, 1999, 2009	Modified Incremental, Modified Federal with NAPCOM (2009)	All Levels: 34.66% State: 38.26%	VMT, ESALs, Axle-Miles, Ton-Miles	State, Federal, and Local Separately and Combined
New Mexico	1972				
North Carolina	1983	Federal		VMT, ESALs, PCE, Weight Axle-Miles	State and Federal Funds
Oregon	1937, 1947, 1963, 1974, 1980, 1984, 1986, 1990, 1992, 1994, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013	Cost-Occasioned with NAPCOM for Pavement Costs (Since 1999)	31.20%	VMT, Congested PCE, Uphill PCE, Truck-VMT, Basic Vehicle VMT	State, Federal, and Local Combined for Cost Allocation Purposes but State Only for Revenue Attribution Purposes
Pennsylvania	1989, 1990	Federal/ Cost-Occasioned			
Texas	1984, 1985, 1994, 2002				
Vermont	1990, 1993, 2006	Federal	25.70%	VMT, ESALs, ADT	State and Federal Funds
Virginia	1991, 1992	Federal	21.70%	VMT, ESALs, ADT	State and Federal Funds Combined
Washington	1977	Incremental			
Wisconsin	1982, 1992	Federal (1982)	31.70%	VMT, ESALs, PCE, Ton-Miles	State and Federal Funds Combined
Wyoming	1981, 1999	FHWA State HCAS Model	55.80%	VMT, Vehicle Size, Horsepower, Weight	

Source: Balducci and Stowers 2008. Adapted from ECONorthwest et al. (2005). Updated by ECONorthwest through 2014.

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### ADDITIONAL HCAS STUDIES

#### **Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees (MN/DOT): Task 1 Report – 2009 Minnesota Highway Cost Allocation Study.**

Prior to the 2009 HCAS, Minnesota had conducted only one HCAS, roughly twenty years ago (published in 1989). Minnesota's 2009 HCAS was conducted by a faculty member and research assistant in the Engineering Department at the University of Minnesota. The study was conducted using FHWA's State HCAS program (HCASP), relying on some national default data and state-specific data when available. MNDOT provided financial (revenue and expenditure) and traffic data for the four-year period of July 2003 to 2007. Thus, the study is retrospective, in that it uses prior year expenditures and VMT; the study does not forecast future year spending, future expenditure work types, or VMT.

Following the Federal HCASP methodology, the study relied on the mapping of twelve HPMS vehicle classes into the 20 HCASP vehicle classes. The study used data from eleven weigh

stations to develop distributions of registered Gross Weight for the vehicle classes. Default weight distributions from HCASP were used for those vehicle classes where the raw weigh station data could not be mapped into the HCASP vehicle classes.

The study found that the share of revenues from heavy vehicles is less than their share of costs.

Three "what-if" scenarios were analyzed to determine equity ratios under three different tax policies:

1. Increase in fees paid by vehicles greater than 16,000 lbs. by 26%.
2. Increase in the diesel tax by 25%.
3. Introduction of a weight-distance tax for vehicles more than 57,000 lbs.

#### **Revenue Attribution**

All federal, state, and local highway user revenues were included in the Minnesota HCAS. Federal revenues are based on those reported in the FHWA's Highway Statistics. The Federal HCASP contains default federal tax rates and attributes federal revenues to vehicle classes based on those rates and the VMT inputs. State highway user fees include motor fuel taxes, registration and license fees, vehicle sales tax, and an ad valorem tax. Similar to Nevada, Minnesota seems to include revenues that are diverted to non-highway uses. In the Minnesota HCAS, attributed state revenues exceed allocated state expenditures by 27%.

**Cost Responsibility**

Following the Federal State HCAS Program, the Minnesota HCAS categorized highway-related expenditures into 18 work categories. The work categories are typical highway project categories such as pavement (new, repair, etc.), bridge (new, replacement, rehabilitation), maintenance and administrative categories. Expenditures are also categorized by functional class, though administrative expenditures, rest area maintenance, state police and fuel/registration collection costs are not assigned a road functional class.

**Equity Ratios and Findings**

Like the Nevada HCAS, the Minnesota HCAS reports unadjusted and adjusted equity ratios. The unadjusted equity ratio is computed as gross revenues divided by expenditures for each vehicle class and the adjusted equity ratios are the ratio of a vehicle class' revenue share to their share of expenditures. Revenue per mile and cost per mile for each vehicle class is reported along with equity ratios, with equity ratios for state and federal reported separately.

The study finds that vehicle classes with weights greater than 16,000 lbs. have adjusted ratios less than 1.0 for state ratio and vehicles under 26,000 lbs. have federal plus state adjusted equity ratios greater than 1.0.

The scenario analysis demonstrates that a 25% increase in the diesel fuel tax is more effective at bringing the heavy vehicle equity ratios closer to 1.0 than a 25% increase in heavy vehicle fees. Both of these two policy scenarios are more effective at bring equity ratios closer to 1.0 for vehicles between 16,000 and 50,000 lbs., but adjusted equity ratios remain rather low for vehicles weighing more than 50,000 lbs.

The third "what-if" scenario examined equity ratios using weight-mile tax applied to vehicles weighing 57,000 lbs. and greater. The weight-mile tax rates were estimated by fitting a segmented regression model to the difference between the allocated cost per mile and current revenue per mile using registered gross vehicle weight categories. Equity ratios for heavy vehicle classes are closer to 1.0—in particular the equity ratio for five-axle tractor trailers is 1.03 under the weight-mile tax. However many vehicle classes still have equity ratios under 1.0.

# Appendix B4: Issue Paper

Recommendations

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## PROBLEM STATEMENT

Cost responsibility is the principle that those who use the public roads should pay for them and, more specifically, that users should pay in proportion to the road costs for which they are responsible. For more than 80 years, Oregon has based the financing of its highways on the principle of cost responsibility.

Oregon voters ratified the principle of cost responsibility in the November 1999 special election by voting to add the following language to Article IX, Section 3a (3) of the Oregon Constitution: “Revenues . . . that are generated by taxes or excises imposed by the state shall be generated in a manner that ensures that the share of revenues paid for the use of light vehicles, including cars, and the share of revenues paid for the use of heavy vehicles, including trucks, is fair and proportionate to the costs incurred for the highway system because of each class of vehicle. The Legislative Assembly shall provide for a biennial review and, if necessary, adjustment, of revenue sources to ensure fairness and proportionality.”

The constitutionally-mandated biennial review is accomplished through highway cost allocation studies, such as the one this issue paper is a part of. In a highway cost allocation study, fairness and proportionality are quantified using equity ratios. An equity ratio is the ratio of the share of revenues paid by a particular class of vehicles (e.g., light vehicles) to the share of costs imposed by that class of vehicles.

When perfect equity is present, the equity ratio will be 1.0000 and no adjustment will be required. One cannot expect perfect equity

to exist in the real world and if it did exist, it would not last for long and measurement and forecast errors likely would prevent its detection. Every Oregon HCAS since 1999 has found a small inequity in one direction or the other. When presenting the findings of a highway cost allocation study to the Legislature, one should also convey the amount of uncertainty around the estimated equity ratios being presented. For the past seven studies, we have told the Legislature that the combination of measurement and forecasting errors could result in our estimated being wrong by as much as five percent. In each of those studies, the estimated equity ratios were well within five percent of perfect equity.

As is the rule generally in sound public policy, the predisposition is to leave current law in place unless there is a good reason to change it. In other words, the null hypothesis is that current highway user fees are close enough to equitable and adjustment is not required.

When attempting to determine whether sufficient inequity exists to require adjustment of user fee rates, two kinds of errors are possible:

**Type I Error** results in incorrectly rejecting a true null hypothesis. In this case, that would mean deciding that sufficient inequity exists to require adjusting rates, when in fact it does not.

**Type II Error** results in failing to correctly reject a false null hypothesis. In this case, that would mean deciding that sufficient inequity to require adjusting rates does not exist, when in fact it does.

In a wide variety of contexts, public policy is willing to allow more Type II errors in order to achieve fewer Type I errors. For example:

- In criminal law, safeguards to prevent the conviction of innocent people sometimes result in the acquittal of guilty people.
- In health policy, safeguards to prevent the use of dangerous or ineffective drugs sometimes result in delays in approving safe, effective drugs

While the stakes are lower, the same principles apply when deciding whether to adjust highway user fee rates to promote equity. Unless there is convincing evidence that the estimated inequity is real and likely to persist, the principles of sound policy require holding off on changing highway user fee rates.

### FINDINGS OF RECENT STUDIES

The seven most recent Oregon Highway Cost Allocation Studies all have found equity ratios well within five percent of perfect equity and the study team has not recommended that user fee rates be adjusted to promote equity. The 2011 Efficient Fee Study, which allocated costs using an alternative method, also produced equity ratios within five percent of perfect equity.

Oregon’s user fees have consistently resulted in near-equitable incidence despite changing circumstances that otherwise would have led to inequity. This is because each time user fee rates are adjusted for other reasons (e.g., OTIA, JTA) the Legislative Revenue Office uses the same highway cost allocation model to design equitable rate structures that is later used to estimate the extent to which those rate structures are equitable.

**Table 1: Equity Ratios from Recent Oregon Highway Cost Allocation Studies**

Study	Light	Heavy
2013	0.9927	1.0139
Trad. 2011	0.9954	1.0089
Eff. Fee 2011	0.9874	1.0251
2009	0.9915	1.0173
2007	0.9933	1.0129
2005	1.0030	0.9940
2003	0.9920	1.0160
2001	1.0027	0.9952

Table 1 shows the equity ratios for light and heavy vehicles from recent studies.

As Table 1 illustrates, the equity ratio for heavy vehicles is always significantly farther from one than is the ratio for light vehicles. This will always be the case as long as the costs and revenues associated with light vehicles are significantly larger than those associated with heavy vehicles. For example, if revenues from light vehicles are twice as large as revenues from heavy vehicles, then moving one million dollars of revenue from one category to the other will have twice as much effect on the equity ratio for heavy vehicles. Light vehicles in Oregon tend to impose about two thirds of total costs and pay about two thirds of total revenue. As a consequence, the equity ratios for heavy vehicles tend to be about twice as far from one as those for light vehicles.

When we say that the combination of measurement and forecasting error can result in estimated equity ratios that are off by up to five percent, that means those errors will always result in heavy-vehicle equity ratios that are

more than five percentage points away from one before the light-vehicle equity ratio is far enough away for us to be confident that it is truly different from one. Under current, informal policy we therefore would not recommend changing user fee rates solely to promote equity unless the light-vehicle equity ratio were more than five percentage points away from one.

**PROPOSAL TO REDUCE THE RISK OF TYPE I ERROR**

This issue paper was requested by the Study Review Team for the 2015 Oregon Highway Cost Allocation Study to explore the advisability of replacing the informal policy that has guided the development of recommendations to the Legislatures to date with a formal policy that includes additional protections against Type I errors.

The additional protections might include:

- Requiring significant inequity to persist for at least two studies before recommending adjustment of rates.
- Using a moving average of equity ratios from two or more studies to identify significant inequity.

Either of these protections would succeed in preventing a Type I error in a single study from triggering unwarranted legislative action. If either involved more than two studies, it could cause a Type II error to delay the correction of real inequities for at least two years.

If two studies are involved, both would be equally effective at identifying a real, persistent inequity. The moving average standard would also require adjustment of rates if a single study showed a large enough inequity.

Because Oregon’s studies are prospective, requiring a second biennial study to corroborate findings of significant inequity would allow such inequity to exist for only two years (not four as would be the case if the studies were retrospective). When conducting a study, it should be possible to determine the extent to which forecasting error caused the immediately-prior study to predict inequity.

None of these potential additional protections would have had any effect in the last seven studies (14 years).

**CONCLUSIONS**

The study team recommends adopting a formal policy that would be convenient for future studies to also adopt. That policy would have two components:

1. To be considered significantly different from perfect equity, the light-vehicle equity ratio must be less than 0.9500 or greater than 1.0500.
2. To necessitate adjustment of user-fee rates, significant inequity in the same direction must be found in two consecutive studies. Upon the first finding of significant inequity, the study team would warn the Legislature, but would not recommend immediate adjustments to highway user fees.

# Appendix B5: Issue Paper

Northwest Economic Research Center

Carbon Tax

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## EXECUTIVE SUMMARY

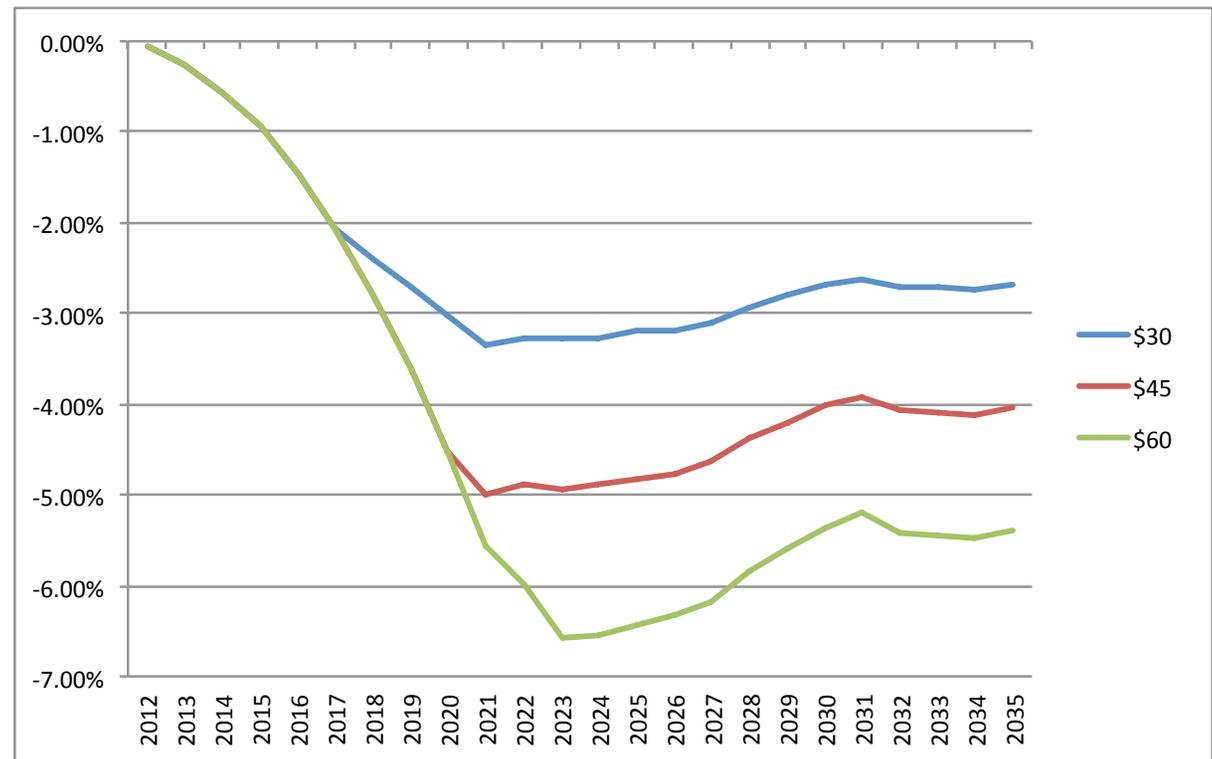
Countries, states, provinces, and cities around the world are considering and implementing a broad range of carbon emissions reduction programs in response to climate change. One of these methods is a carbon tax, which is a tax applied to fuels or activities based on their carbon content. Transportation activities are a major contributor to carbon emissions and would therefore be affected by a carbon tax. In light of the recent discussion in Oregon regarding carbon pricing, this issue paper estimates the impact on the demand for transportation fuels of a carbon tax at various carbon prices using two different estimation techniques.

In 2013, the Northwest Economic Research Center (NERC) released *Carbon Tax and Shift: How to Make it Work for Oregon's Economy*. The report estimated the economic and emissions impacts of implementing a carbon tax in Oregon based on the British Columbia (BC) carbon tax. The BC carbon tax is revenue neutral- collected revenues are used to offset existing taxes and fees. In *Carbon Tax and Shift*, the revenues were modeled mainly as reductions in personal and corporate income tax rates.

The study utilized two models: The Carbon Tax Analysis Model (C-TAM) and IMPLAN, an input-output software. [Figure 1](#) shows the expected decrease in transportation fuel consumption relative to a forecasted baseline for three different carbon prices.

Two shortcomings of the study were the lack of dynamic feedback and tax incidence shifting, which would have an impact on final fuel

**Figure 1: Percent Change in Transportation Fuel Consumption from Baseline (\$/ton CO<sub>2</sub>e)**



consumption. In 2013, the Oregon Legislature passed SB306 which directed the Legislative Revenue Office (LRO) to conduct a study of the emissions and economic impacts of a clean air tax or fee in Oregon. LRO contracted with NERC to conduct the analysis, which addressed both of these issues.

For the SB306 analysis, NERC and the study team created a new Oregon emissions model and combined its results with those of REMI, an economic simulation software model. The new estimation methodology allowed for the incorporation of dynamic feedback and a

broader range of carbon prices and modeled revenue uses. [Figure 2](#) (on the following page) shows the expected decrease in household motor fuel demand relative to a forecasted baseline for the SB306 study.

Other results from the SB306 study can be found in the REMI Model Results section (p. 127).

While a carbon tax would almost certainly reduce demand for transportation fuels (relative to a baseline with no carbon pricing), this reduction in demand would not necessarily be tied to decreases in economic activity. Revenues could be used to reduce business

expenses or increase household income and could stimulate economic activity. Carbon pricing schemes in other parts of the world have been successful at reducing carbon emissions while creating minimal economic impact

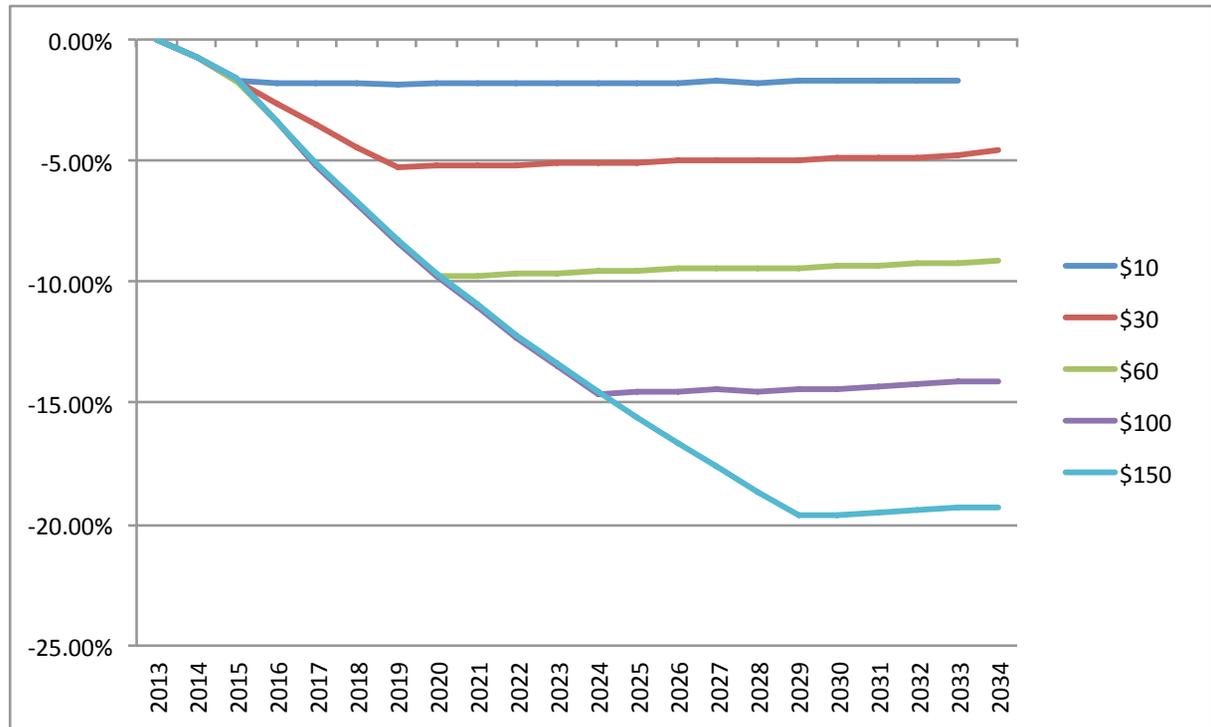
## INTRODUCTION

Innovative approaches to emissions reduction, such as carbon pricing, have received increased attention amidst rising public concern about climate change and the early successes of similar programs around the world. As Oregon policymakers weigh the economic and environmental costs and benefits of pollution reduction, a state carbon tax has been proposed to address each. Individual cities, states/provinces, and countries have already implemented a carbon tax, including British Columbia, numerous countries in Europe, Asia, and the US metro areas of Boulder, CO and San Francisco, CA. The impacts of such a tax on these regions are a useful tool when determining possible implications of such a policy in Oregon. While the overall impacts on the economy are distributed broadly, certain sectors will be affected more than others. This issue paper will investigate the literature covering the impacts of a carbon tax on the transportation sector and report on estimated changes to transportation fuel use due to a carbon tax.

The Northwest Economic Research Center (NERC) conducted a study analyzing how a British Columbia-style carbon tax would affect the Oregon economy.<sup>1</sup> NERC's report used baseline scenarios in which funds collected via the carbon tax were repatriated through reductions in personal or corporate

<sup>1</sup>Liu, Jenny and Jeff Renfro (2013), Carbon Tax and Shift. Northwest Economic Research Center. Portland State University.

**Figure 2: Percent Change in Household Motor Fuel Demand (\$/ton CO2e)**



income taxes, with a portion reinvested into targeted sectors and programs. NERC's report consistently showed the transportation sector experiencing disproportionately negative effects. The study estimated transportation employment losses near 3%, despite overall employment increases in the entire economy, in each scenario considered. Thus, the market efficiency gained by correcting a negative externality appeared to come in part from this sector's burden.

NERC has updated its economic and emission estimates as part of a study funded by the passage of SB306 in 2013. SB306 requires

a new study which looks at geographic and industrial disparities of a tax in greater detail, and investigates other repatriation options. This new report was recently released in December 2014, and portions of the modeling related to fuel demand are used in this paper. These newer fuel demand estimates take into account industry price pass-throughs and dynamic reactions to energy price changes.

The implementation of a carbon tax would have an immediate effect on the retail price of gasoline. The amount of the increase would of course vary depending on the size of the tax, and studies have shown that an increase

in the price of gasoline decreases demand. Furthermore, Davis and Kilian<sup>2</sup> (2009) find that consumer demand for gasoline is more sensitive to tax increases than to changes in the price of gas. Taking a price increase as given, one would expect consumer behavior to change; in the short run, consumers face a limited set of alternatives, eliciting the smallest change in fuel demand. In the longer term there are additional opportunities, including public transportation, carpooling, and fleet substitution to more fuel efficient vehicles.

The transportation and shipping industries may likewise experience an increase in fuel costs, and thus a reduction in revenue, illustrating how a carbon tax might negatively affect the transportation sector. However, if a portion of the tax revenue is reinvested in transportation infrastructure, there could be significant public welfare gains. To the extent that the reinvested revenue funds public works projects which support less carbon intensive transportation, the tax can simultaneously address both climate change and infrastructure improvement. Parry and Williams<sup>3</sup> (forthcoming) examine the need for transportation policies which address negative externalities from carbon emissions, stating that revenue can be used to fund these policies.

The purpose of this paper is to estimate the changes in demand for transportation fuels due to a carbon tax. Changes in fuel demand from an expected baseline will have impacts on Highway Trust Fund revenues, which will alter the state's ability to fund maintenance and construction of roads. The previously

mentioned *Carbon Tax and Shift* and the SB306 analysis includes estimates of impacts on emissions, income, employment, output, and state revenues and are resources for readers interested in the broader impacts of the policy.

The study team made an effort to suggest implementation methods which build on existing state programs or revenue collection methods, but differentiating between different types of road users would add a level of complexity to applying the carbon tax to commercial road users. The current method of imposing weight-mile fees on commercial road users takes into account the weight class of the vehicle. As the study team has envisioned it, a carbon tax would not differentiate between different weight classes. Following British Columbia, this study assumes that the tax is imposed at the wholesale level and is based on the calculated carbon content of combustion of the fuel, and the quantity of fuel purchased. If carbon tax collection was able to take advantage of current weight-mile fee collection mechanisms, a weight component could be incorporated into the collection of the tax. Experts could develop estimates of the carbon content produced by combusting the same quantity of fuel in different classes of vehicles. With this information, a weight-class specific carbon content per mile parameter could be developed. When commercial users report miles traveled in Oregon and pay the weight-mile fee, an additional fee could be added based on the estimated carbon produced by the vehicle during Oregon operation.

## EXISTING CARBON PRICING POLICIES

### BRITISH COLUMBIA CARBON TAX

Implemented in 2008, the British Columbia carbon tax provides an example of how such a measure might function in Oregon. Cultural and environmental similarities, as well as geographic proximity between British Columbia and Oregon make BC a particularly relevant case study. The tax was phased in over a 5 year time period, beginning at \$10 per ton of carbon dioxide equivalent (CO<sub>2</sub>e), and increasing by \$5 per ton of CO<sub>2</sub>e increments until it reached the level of \$30 per ton of CO<sub>2</sub>e in 2012. The key feature of the tax in BC is revenue neutrality—its proceeds are entirely repatriated into the provincial economy through reductions in other tax sources and direct rebates.

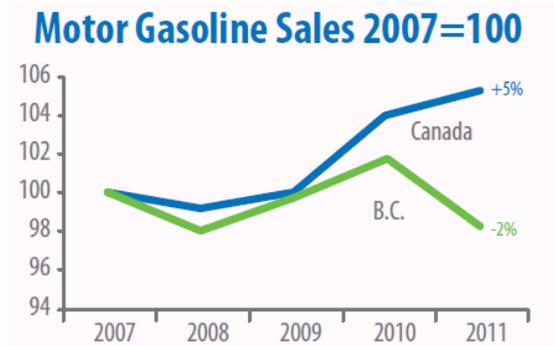
The results of the BC carbon tax have generally been considered favorable, though there are conflicting reports on its efficacy. The Pembina Institute<sup>4</sup> conducted confidential interviews across industry sectors, finding consensus on both the need for climate change mitigation and the public (as opposed to private) leadership needed to drive policy. The majority of interviewees considered the consequences of the carbon tax to be positive. Unfortunately, while the transportation organization field was represented in the interviews, freight businesses in particular were omitted, limiting the survey's applicability to this issue paper.

<sup>2</sup>Lucas W., Davis and Lutz Kilian (2009), Estimating the Effect of a Gasoline Tax on Carbon Emissions, working paper. Cambridge, MA: National Bureau of Economic Research.

<sup>3</sup>Forthcoming in Ian Parry, Adele Morris and Robertson Williams, Carbon Taxes and Fiscal Reform: Key Issues Facing US Policy Makers. Routledge, forthcoming. The report we found was a draft paper titled Implications of Carbon Taxes for Transportation Policies. Ian Parry responded to a citation request, instructing that we cite as above.

<sup>4</sup>Horn, Matt, et al. (2012), British Columbia's Carbon Tax: Exploring perspectives and seeking common ground. Alberta: The Pembina Institute.

**Figure 3: British Columbia Motor Gasoline Sales (2007\$=100)<sup>8</sup>**



Rivers and Schaufele<sup>5</sup> researched the gasoline demand response associated with the BC carbon tax using econometric methods. They found that the demand response associated with a carbon tax is larger than that of price changes in gasoline in the absence of a carbon tax. As noted, implementing a tax creates significant short and long-run decreases in demand for gasoline. The River and Schaufele study does not specifically address the transportation sector, but its estimated demand changes for gasoline can be extended to the transportation industry, which relies heavily on the use of gasoline. Elgie and McClay of Sustainable Prosperity<sup>6</sup> confirmed the effectiveness of the BC carbon tax, illustrating significant reductions in the use of fossil fuels without adverse economic effects. Conversely, Rayne and Forest<sup>7</sup> concluded that pre-existing trends prior to the implementation of the carbon tax prevent accurate determination the tax's economic and environmental impacts.

Despite an abundance of literature surrounding the BC carbon tax, most studies do not directly address the transportation industry. As the number of years of available data increases, there will be growing opportunities for research specifically addressing the transportation sector. Currently, much analysis relies on adapting aggregate results to an individual portion of the economy. Figure 3 shows the changes in motor gasoline sales in BC in the first four years of the carbon tax. Importantly, these results are not controlled for other fuel sale determinants, and the BC government implemented a suite of carbon reduction methods during this period.

#### IRELAND'S CARBON TAX

Ireland's carbon tax of €15 (\$20.39)<sup>9</sup> per ton of CO<sub>2</sub>e was implemented more recently than the BC tax, in 2010. The implementation of the tax consisted of three phases. The first phase applied to transportation fuels, such as automotive gasoline and diesel, followed by a tax on non-transportation fuels. Solid fuels, such as coal and peat, were introduced last, and at a lower rate. The level of the tax has also incrementally risen to €20 (\$27.19) per ton of CO<sub>2</sub>e. Since the tax was first introduced on transportation fuels, short run effects on the industry should be expected, particularly with regards to fuel prices and demand.

Obtaining public support for the tax was largely tied to Ireland's financial crisis, a subject investigated by Convery, Dunne and Joyce.<sup>10</sup> At the time of implementation, Ireland experienced

significant financial troubles, including large debt obligations. Revenues gained by the tax are thus intended in part to pay down these debt obligations. Much of the country's purported benefit of the carbon tax was the ability to address these fiscal issues without increasing the corporate income tax.

The report by Convery, Dunne and Joyce showed a reduction in CO<sub>2</sub> emissions in the transportation industry following the tax. However, because Ireland was experiencing a large-scale financial crisis, it is difficult to attribute changes in consumption with the implementation of the tax. Another complicating factor is that in 2008 the Irish government transformed the basis of taxation for the vehicle (VRT) and motor tax systems, making it even more challenging to disentangle the effect of the carbon tax. What is clear is that the carbon tax adds to the price of transport fuel paid by consumers. There is presumably a demand response to this change. As more years of data become available, allowing for proper statistical analysis, estimates of how the tax ultimately affects the transportation industry will become feasible.

#### OTHER CARBON TAXES AROUND THE WORLD

It should be noted that BC and Ireland are far from the only locations to have considered and/or implemented unit carbon taxes. Australia introduced a carbon tax in 2012 (which has since been repealed), and South Africa will

<sup>5</sup>Rivers, Nicholas and Brandon Schaufele (2012), Carbon Tax Salience and Gasoline Demand, working paper. Ottawa: University of Ottawa.

<sup>6</sup>Elgie, Dr. Stewart and Jessica McClay (2013), BC's Carbon Tax Shift After Five Years: Results. Ottawa: Sustainable Prosperity.

<sup>7</sup>Rayne, Sierra and Kaya Forest, British Columbia's carbon tax: Greenhouse gas emission and economic trends since introduction. Saskatchewan: Saskatchewan Institute of Applied Science and Technology.

<sup>8</sup>Making Progress on B.C.'s Climate Action Plan 2012. Pg. 10.

<sup>9</sup>Conversions based on 6/20/14 exchange rates.

<sup>10</sup>Convery, F. J., L. Dunne and D. Joyce (2013), Ireland's Carbon Tax and the Fiscal Crisis: Issues in Fiscal Adjustment, Environmental Effectiveness, Competitiveness, Leakage and Equity Implications, OECD Environment Working Papers, No. 59, OECD Publishing. <http://dx.doi.org/10.1787/5k3z11j3w0bw-en>.

implement its version of a carbon tax in 2016. Several European nations have already introduced carbon taxes, as well as some countries in Asia. Each is distinct in its specific coverage and magnitude; thus results cannot be compared directly across regions. However, important information can be gleaned from the experiences of these countries. As more research emerges on the results of carbon taxes in other regions, transportation-specific effects will be among the applicable lessons available.

## TRANSPORTATION IMPACTS FROM CARBON TAX AND SHIFT

In the aforementioned “Carbon Tax and Shift” report, NERC used a program called The Carbon Tax Analysis Model (C-TAM) to estimate the emissions and fuel demand impact changes due to a carbon tax. C-TAM uses the Energy Information Administration (EIA) forecast for the Pacific Region as a basic input. The forecast is pro-rated for Oregon, and elasticities are used to estimate new fuel demand associated with a carbon tax. NERC estimated the change in transportation fuel demand under a variety of carbon prices.

### CTAM METHODOLOGY<sup>11</sup>

The gold-standard for energy forecasting is the National Energy Modeling System (NEMS) run by the Energy Information Administration (EIA). NEMS includes sophisticated economic modeling modules as well as dynamic feedback. Simulation in this model requires

extensive training and is expensive. In order to run estimates of the net impacts of an Oregon Carbon Tax, we combined two different modeling techniques that draw from this more complicated analysis.

The process began with the Carbon Tax Analysis Model (C-TAM)<sup>12</sup>, originally created by Keibun Mori for the Washington State Department of Commerce. C-TAM incorporates NEMS energy forecasts and local economic projections, and features an interface appropriate for non-technical users. We adapted the Washington State model for use in Oregon.

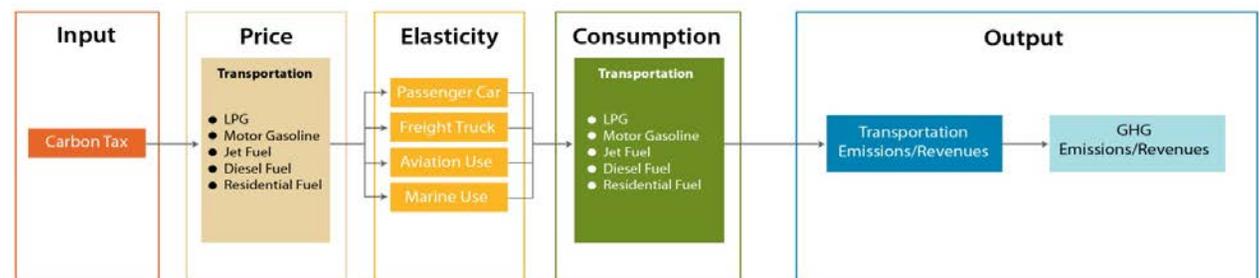
C-TAM is a production-based model, meaning some sources of GHG emissions are not captured by the model. The emissions from fuel use in the production of cement, for example are captured, but the GHG given off by the materials are omitted. Likewise, emissions from tractors and trucks used on agricultural land are captured, but GHG given off by fertilized fields are not captured. We chose to use a production-based model because the BC Carbon Tax (our model) applies to fuels *combusted* in BC, and is not applied to non-production emissions

sources. The model also ignores the emissions generated by using fuels purchased in another states but used in the Oregon's transportation sector.

C-TAM begins with the energy-usage forecast for the Pacific Region created using NEMS. This baseline forecast can be customized to include the effects of different carbon mitigation policies. We chose to use the Extended Policy forecast as the baseline. Extended Policy incorporates all laws and regulations currently on the books and assumes that energy efficiency and carbon mitigation regulations that are normally renewed will continue to be renewed, and that energy efficiency standards that are normally altered upon renewal will continue to be altered accordingly. This forecast also assumes full implementation of the new CAFE standards<sup>13</sup> and the Renewable Energy Portfolio Standard.

It is important to note that the following results assume continued carbon mitigation efforts from policy-makers, and the ensuing changes in behavior by consumers and businesses.

Figure 4: Transportation Sector - Outline of the simulation process in C-TAM



<sup>11</sup>CTAM Methodology section is adapted from Carbon Tax and Shift: How to Make it Work for Oregon's Economy

<sup>12</sup>Mori, Keibun. (2012). Modeling the Impact of a Carbon Tax: A Trial Analysis for Washington State. Energy Policy, 48, 627-639.

<sup>13</sup>For full description of new CAFE Standards, see National Highway Traffic Safety Administration: <http://www.nhtsa.gov/fuel-economy> (Retrieved February 22, 2013)

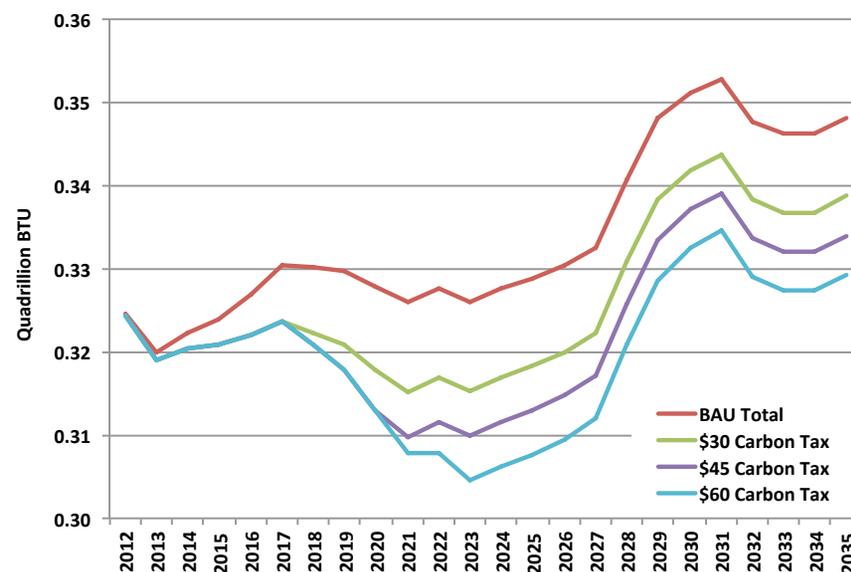
This forecast is then pro-rated using historical Oregon energy-consumption data to create an Oregon energy-usage forecast. Tax revenue and population forecasts from the Oregon Office of Economic Analysis are also used as inputs. In order to estimate the effect of the Carbon Tax, we increase the price of fuels according to the price of carbon and the carbon content of each fuel. Change in usage is predicted based on elasticities drawn from multiple published papers. These elasticities are fuel-specific when possible; when an elasticity estimate has not been computed (or has not been computed recently); the fuel is assumed to have the same elasticity as a comparable fuel. This change in consumption is used to calculate the change in emissions, and the revenue generated by the tax. [Figure 4](#) (on the previous page) diagrams the C-TAM simulation process relevant to the transportation sector.

### MODEL RESULTS

A large portion of the transportation sector<sup>14</sup> relies on carbon-intensive fuels. This fact, and the high costs associated with developing and adopting less carbon intensive transportation energy sources, leads to a sector that is relatively unresponsive to changes in fuel price. Given this behavior the trend in fuel use forecasted by C-TAM should exhibit a sluggish decline in fuel use as a price on carbon is phased in. Such is the case for each of the three price scenarios visualized in [Figure 5](#). As discussed immediately above, C-TAM relies on estimates of price elasticity of demand in order to model future fuel demand. These elasticity estimates as well as the NEMS fuel use forecast are key drivers of the forecasted fuel demand reported here.

The C-TAM model used for these three price scenarios assumes that a starting price of \$10 per ton of CO<sub>2</sub>e was introduced in 2012. This price then increases by \$5 per year (or \$10 per year in the case of the \$60/ton cap) until the maximum price is reached. Interim year maxima are thus \$30 in 2016, and \$45 in 2019. Between 2016 and 2021, the price continuously increases for the \$45 and \$60 price scenarios, and forecasted fuel usage expectedly declines at a greater rate than in the \$30 price scenario. The large initial decline in fuel use between 2017 and 2021 can mostly be attributed to a steady drop in demand for motor gasoline. The sharp increase in fuel use between 2023 and 2031 is similarly driven

**Figure 5: Transportation Sector - Adjusted Fuel Consumption<sup>15</sup>**



by a substantial rise in E85 fuel consumption. This increase in E85 use peaks in 2031 and slowly declines until it stabilizes in 2034. The only other notable trend through the forecasted period is that the growth in demand for distillate fuel (i.e., diesel fuel) remains positive and fairly steady. The relative unresponsiveness of diesel fuel demand is consistent with existing transportation systems and infrastructure. The current system is heavily dependent on ground and rail transport for freight movement, both of which consume large amounts of diesel fuel. C-TAM's prediction that demand for diesel fuel will hold steady and grow seems plausible barring the development and adoption of a cost competitive alternative.

There are a few important caveats to discuss regarding the underlying mechanics and assumptions of C-TAM. First, while C-TAM's baseline fuel use forecast is derived using a dynamic model (i.e., National Energy Modeling System (NEMS)) the adjusted forecast, due to a price on carbon, is not dynamic. Prices on carbon will likely cause inter-industry burden shifting. For example the transportation sector may effectively shift much of its tax burden onto the industrial sector; these shifts are not reflected in C-TAM estimates. In the REMI section of the report, we report

<sup>14</sup>In the C-TAM portion of this report, the transportation sector includes transportation of goods and freight, as well as private vehicle operation.

<sup>15</sup>As a rule of thumb, a carbon price of \$1/ton CO<sub>2</sub>e corresponds to an increase in the price of gasoline by a little less than \$0.01 per gallon. A carbon price of \$30/ton CO<sub>2</sub>e would increase prices at the gas pump by ~\$0.29 per gallon.

results which do include price shifting. This does alter our estimates of industry-specific employment impacts. Second, C-TAM does not take into account transportation policies that may be targeted at incentivizing development and adoption of less carbon intensive fuels and fuel efficiency technologies. Both of which could substantially influence the relative sensitivity to changes in fuel prices.

Figure 6 shows the same information as Figure 5. It is reconfigured to show the percent reduction from the business as usual baseline.

## SB306 ESTIMATES

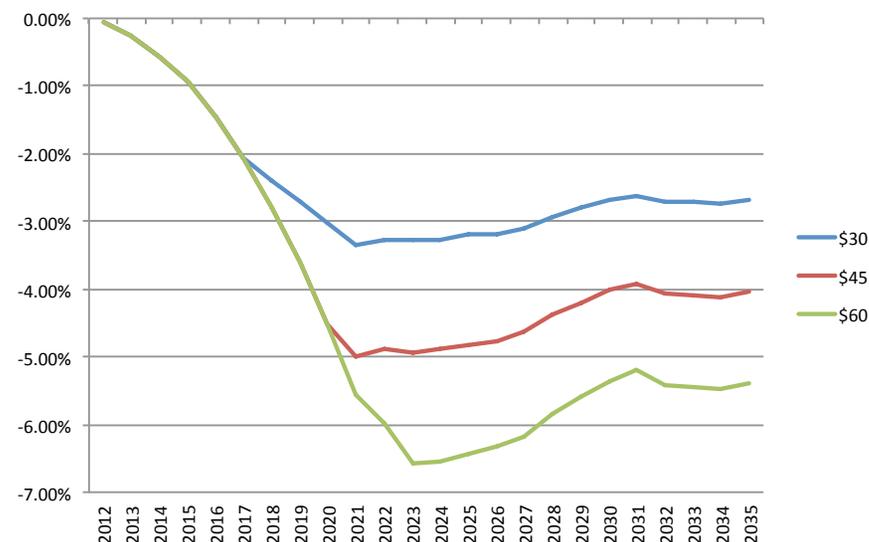
In 2013, the Oregon Legislature passed SB306, which required the Legislative Revenue Office (LRO) to conduct a study of the economic and emissions impact of implementing a clean air tax or fee. LRO contracted with NERC to conduct the study. For this updated analysis, NERC used REMI (described below) and worked with two Portland State University physicists to create a custom Oregon emissions model. These two models in tandem provided greater modeling flexibility and capture dynamic effects of tax implementation.

### THE REMI PI+ MODEL

NERC used a six-region model of the Oregon economy developed by Regional Economic Models, Inc. to analyze the dynamic effects of the tax across the state. The REMI model is widely used for planning and policy analysis at the national, state, and local level. It integrates input-output, econometric, and general equilibrium approaches from economics to produce realistic simulations of the complicated channels through which economic shocks move through the economy. It is thus a dynamic forecasting tool; by first estimating the complex historical relationships between economic entities and activities, the model is able to project outcomes for virtually any user-defined policies and economic circumstances.

Data underlying the REMI model includes historical personal income, employment, and population at each geographic level from the Bureau of Economic Analysis, Bureau of Labor Statistics, and US Census Bureau. The responses of firms and workers to any economic shock will vary across industries and regions, so these data are incorporated at a high

**Figure 6: Percent Change in Transportation Fuel Consumption from Baseline (\$/ton CO<sub>2</sub>e)**



level of disaggregation. The model also uses historical fuel costs, housing prices, corporate tax rates and structures, and several other supplemental time series to estimate particular regional characteristics. Employment projections from the BEA and BLS are incorporated into REMI's baseline forecast, to which alternative scenarios can be compared.

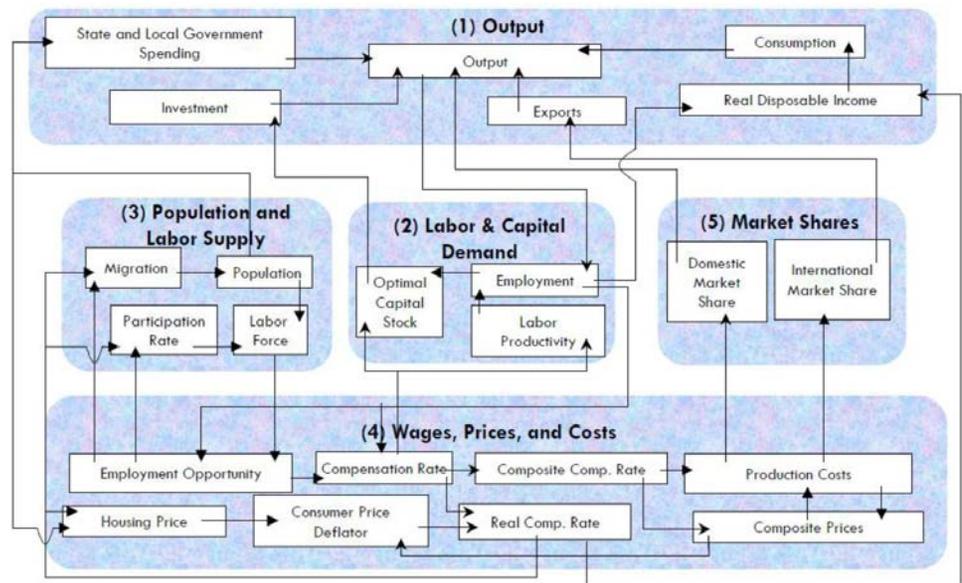
REMI is designed to capture complex interactions between industries and locations. For example, a packaging manufacturer in Portland may require wood fiber originating in the southern Willamette valley, electronics manufactured in the western metro region, and transportation services based in central Oregon in its production process. A supply or employment shock to any link in that chain will have both upstream and downstream effects in the model simultaneous with all of the effects happening in other supply chains, resulting in constantly evolving variables. Household and population dynamics are similarly represented; households (like firms) respond according to standard economic theory to exogenous shocks. This means, for example, that workers in the model will relocate towards better employment opportunities and away from higher living costs. This movement in turn interacts with labor and housing markets over time,

creating a fully dynamic system akin to textbook representations of the macroeconomy. Figure 7 illustrates the basic structure of the model economy in REMI. The pictured schematic represents one given geographic region; equally complex links between regions including migration, inter-regional competition, and cross-border price effects are present in the model but not pictured.

The magnitudes of supply-side and household effects (the arrows in Figure 7) depend on the responsiveness of numerous economic variables to signals and conditions. These elasticities and multipliers are estimated econometrically by REMI, using the observed data above to establish average and expected responses to simulated shocks in the economy. For our study, especially relevant elasticities include the price elasticity of demand for fuel and other goods and services (also central to the C-TAM model) and the marginal propensity to consume different goods. In REMI, households of different income levels have appropriately diverse spending and saving habits. When repatriated carbon tax revenues are allocated to household income quintiles, it is thus possible to track the demand and output impacts across individual industries, which in turn interact with each other in accordance with each industry's estimated elasticity to input prices, interest rates, and so forth.

In essence, the model starts with a detailed representation of the six regions of the Oregon economy (Metro, Northwest, Central, Eastern, Southwestern, and Valley), and introduces changes that cycle through thousands of linkages according to observed relationships. Figure 8 is a map of the regional breakdown. NERC augmented the dynamic processes through which REMI equilibrates for our study to reflect the nexus of carbon emissions, emission tax revenues, employment, and economic output. To briefly illustrate, a carbon tax is introduced in REMI according to the fuel consumption of households and firms in different industries. This creates output and fuel demand effects as consumers and firms respond to higher energy costs as well as a sizeable fund of revenues which are repatriated to the economy. Simply allowing REMI to reach a new equilibrium after this one-time change would conceptually omit an indirect channel of adjustment: if the tax, demand response, and revenue repatriation occurs in one year, the demand response and generated funds will evolve in the second year (fuel demand should be expected to have fallen, and revenues should be expected to follow suit),

**Figure 7: REMI Modeling Schematic**



**Figure 8: Study Regions**



the third year, and so on. NERC incorporated revenue feedback from our emissions model for each scenario in order to capture this effect; its impacts were essentially too small to measure at the lower tax levels, and became noticeable at tax levels higher than \$100.<sup>16</sup>

### ESTABLISHING A BASELINE

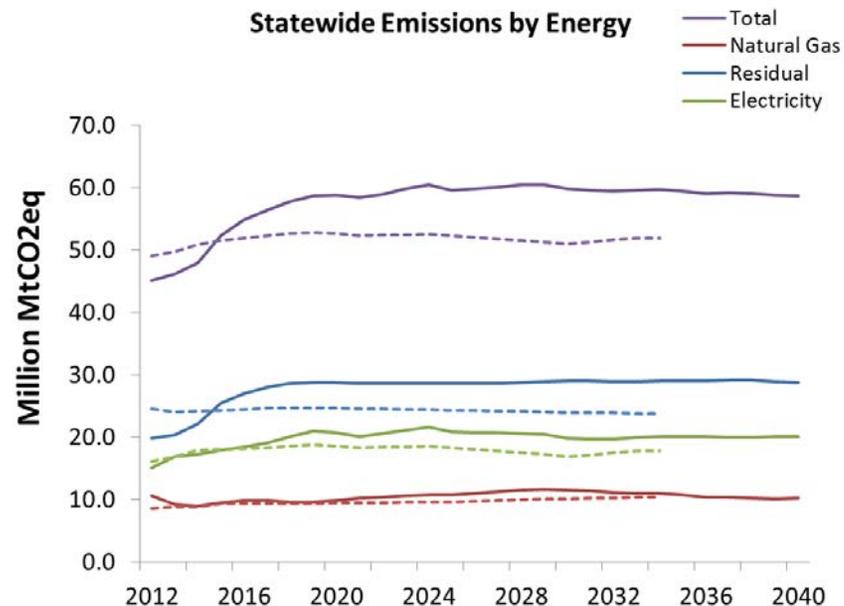
In order to establish a fuel demand baseline within the modeling, we calculated fuel demand by type using REMI's baseline forecast for Fuel Demand and Industry Output. Both measures are expressed in terms of dollars within REMI, requiring us to convert demand in dollars to demand for physical quantities of fuel. We used the EIA forecast for energy prices to make this conversion. Figure 9 shows the REMI-derived fuel demand forecast compared to the EIA/Oregon Department of Energy Forecast for fuel demand in Oregon. Our initial attempt at creating a baseline has the relative proportions of fuel demand correct, but overestimated the demand for electricity and residual fuels.

To solve this, we used the EIA/ODOE baseline numbers as a cap for the REMI baseline projections. The REMI model does not include explicit fuel prices; instead, it uses dynamic, econometrically-derived elasticities which output changes in fuel demand (expressed in dollars) from an expected baseline. By forcing the REMI energy usage forecast to match the EIA/ODOE forecast, we can use expected changes in fuel demand expressed in dollars and industrial output to derive expected changes in physical quantities of fuel demanded, relative to the EIA/ODOE baseline.

### REMI MODEL RESULTS

The first phase in the estimation process established an expected price change relative to the forecasted baseline for each fuel based on the assumed price of carbon. We started with the EIA's forecast of fuel prices, then added an additional cost to each fuel type based on its carbon content. This portion of the estimation process was identical to the method used in the *Carbon Tax and Shift* report above (except for the estimation of electricity price changes). Figure 10 (on the following page) shows the expected percent price deviation from the baseline for motor gasoline for a range of carbon prices. Figure 11 (on the following page) shows the same percent price increase for residual fuels used in commercial and industrial processes. REMI uses a more aggregated fuel breakout than the EIA forecast. The

Figure 9: Fuel Demand Baseline



The modeling outputs related to energy demand are split into categories that do not directly correspond to how Oregonians talk about energy usage in their regular lives. For this study, there are two important definitions to keep in mind while reviewing results:

**Residual Fuels:** these fuels are best understood petroleum-based fuels. In Oregon, this is dominated by petroleum-based transportation fuels like gasoline and diesel.

**Household Motor Gasoline:** this is a subset of the overall residual fuels category. This is the portion of residual fuels which households purchase for transport in private cars. This represents a large portion of overall residual fuels and of the state's overall energy usage.

<sup>16</sup>For a fuller explanation of the estimation methodology, see the Legislative Revenue Office/NERC report on a Clean Air Tax or Fee in response to SB306.

residual fuel category is almost completely motor gasoline and diesel. The expected price change for each fuel type was therefore weighted and used to make an average price change for the residual fuels category.

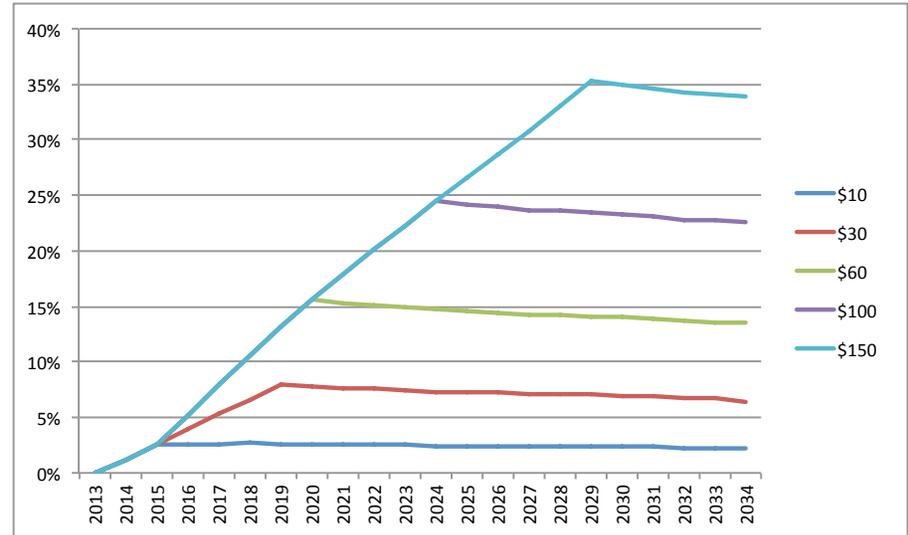
These price changes were used as inputs in REMI. Their overall impacts depend on how tax revenues are used. The following graphs assume that revenue derived from transportation fuels accrue to the state's highway fund, and that of the remaining revenue, 70% is applied to corporate income tax cuts and 30% is applied to personal income tax cuts. This breakdown is similar to the repatriation method employed in British Columbia.<sup>17</sup>

As part of the SB306 study process, NERC received mid- to long-term estimates of Highway Fund disbursements by study region from the Oregon Department of Transportation (ODOT). The formula is based on a weighted Vehicle Miles Traveled (VMT) formula, which applies greater weights to rural miles traveled. The disbursement of these funds, and the associated increase in construction jobs, has an impact on the region-specific economic outcomes. The scenarios reported on in this report all assume that highway funds are disbursed according to the weighted VMT. In the full SB306 study, scenarios are modeled in which the VMT formula is unweighted and the highway fund revenues are used for transportation investments beyond building and maintaining roads and highways.

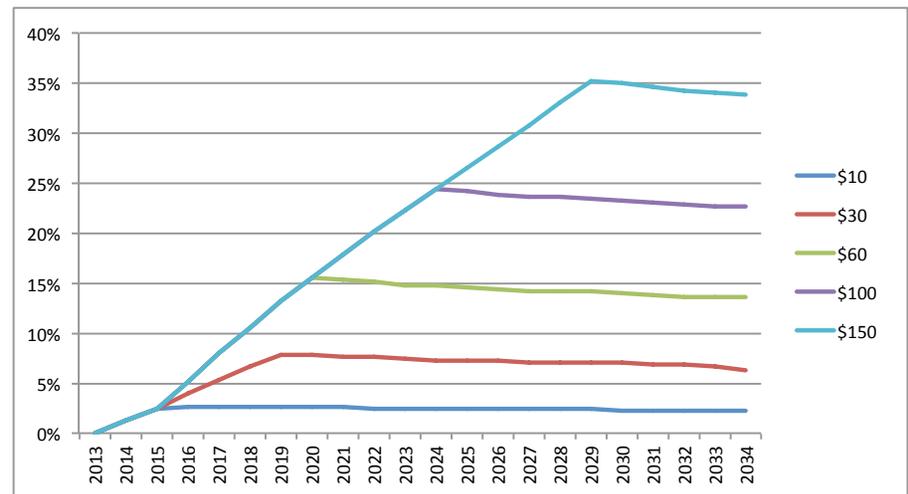
After running scenarios which look at a variety of repatriation and expenditure methods at a variety of prices, we find that for carbon prices of \$60/ton or lower, the repatriation method has a minimal to nonexistent impact on fuel demand. At prices of \$100/ton or more, fuel demand does change based on repatriation method, but the impact is small relative to the overall fuel demand and economic activity in Oregon. For prices of \$60/ton or less, the revenue generated by the policy is small relative to the overall level of economic output in the state. When this revenue is repatriated or expended, the change in economic activity is also small relative to overall economic activity but the price signal created by the carbon tax is still in place.

The following results reflect the estimated net impact of fuel-specific price increases and the repatriation and expenditure method mentioned above. Results are reported for impacts on residual fuel demand, and the household motor gasoline subset of residual fuels.

**Figure 10: Motor Gasoline Percent Price Change from Baseline (\$/ton CO2e)**



**Figure 11: Residual Fuels Percent Price Change from Baseline (\$/ton CO2e)**



<sup>17</sup>The full report which resulted from SB306 shares results for a broad range of scenarios. This scenario is presented here because it is similar to the program implemented in British Columbia, and features a combination of revenue uses seen in other jurisdictions. Overall economic results vary based on the use of the revenue, but the impacts on net changes in demand for transportation fuels are relatively stable.

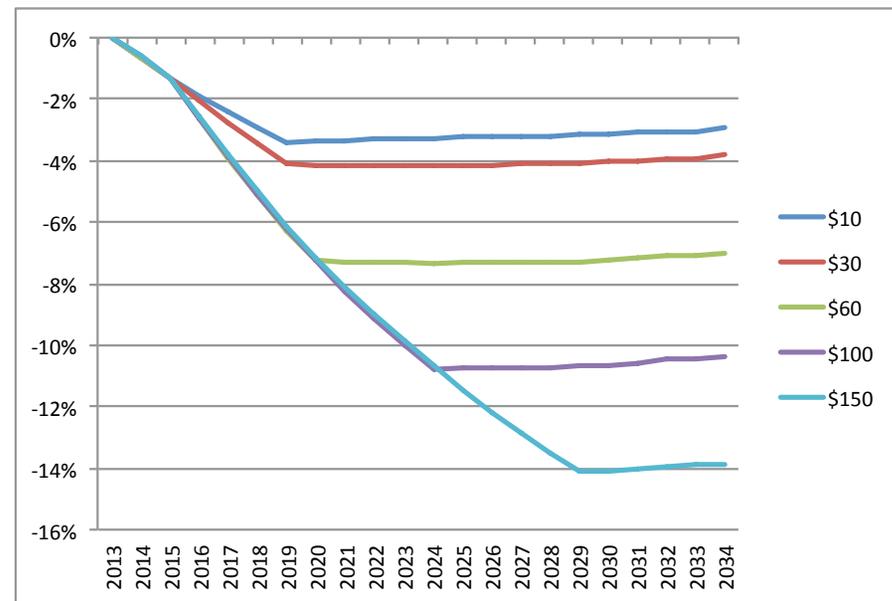
Figure 12 shows the expected decrease in fuel demand for residual fuels due to the implementation of a carbon tax. In this case, residual fuel refers to all petroleum products combusted in Oregon, including motor gasoline for private cars. This category is dominated by transportation fuels for private, commercial, and industrial use. We assume that the price starts at \$10/ton in 2014. For prices of \$10/ton and \$30/ton we assume a \$5/ton annual increase. For all other prices, a \$10/ton annual increase is used.

Figure 13 shows the regional breakdown of the impact on residual fuel demand for the same scenario. The Metro area experiences the largest percentage decline, driven in part by the negative impact on industrial output in the area and the presence of alternative transportation options. Based on historical responses to price changes, the REMI model estimates larger elasticities (i.e. stronger responses to price changes) in the Metro region, relative to the rest of the state. If industrial impacts were proportionately equal across all regions, the expected changes Metro transportation fuel demand would still be greater.

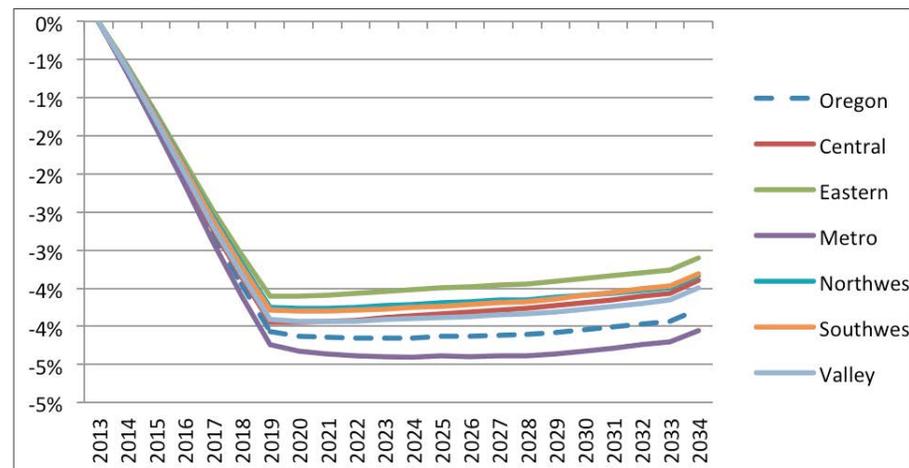
Figure 14 (on the following page) isolates the impact of the carbon tax on motor gasoline used by households for this scenario. This category represents a large portion of Oregon’s fossil fuel usage. The magnitude of change for this category is greater than the overall residual fuel category, in part because some car drivers have alternatives to driving or can easily change driving patterns in response to higher prices. This effect is evident in Figure 15 (on the following page), which shows the regional breakdown of changes in household motor gasoline demand. The Metro region has the largest percentage decrease in motor fuel demand because residents in this area have better access to public transportation and other car substitutes. Rural areas like Eastern Oregon experience the smallest impact because residents have fewer alternatives and need to make budget adjustments in areas other than motor fuel costs.

Relevant to the remit of the Highway Cost Allocation Study panel is the impact of the carbon tax on the Oregon trucking industry. Given the high fuel-intensity of the industry, it would seem safe to assume job losses. Our estimates actually show modest job gains, driven almost exclusively by the increase in the highway fund due to the tax. The increase in highway funding acts as a stimulus to the road construction and maintenance industries across the state. Because highway funds are disbursed

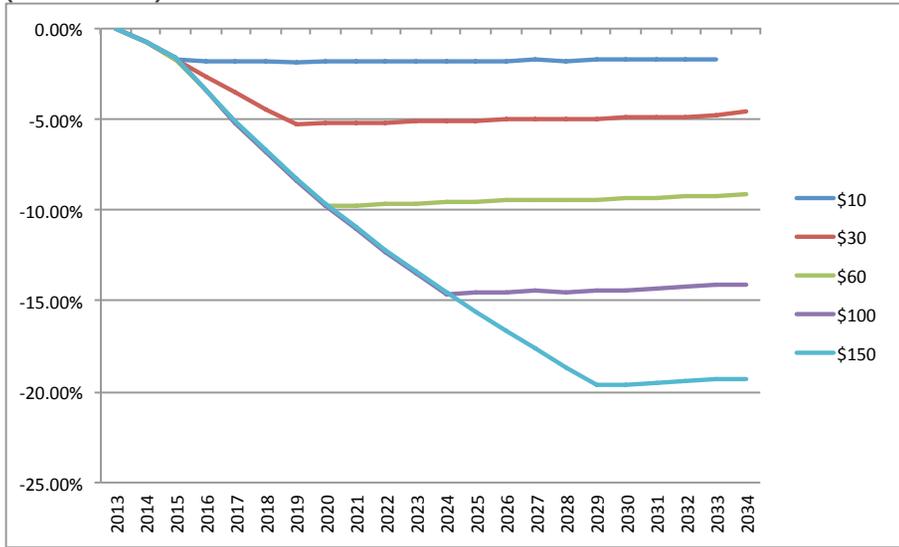
**Figure 12: Percent Change in Oregon Residual Fuel Demand (\$/ton CO2e)**



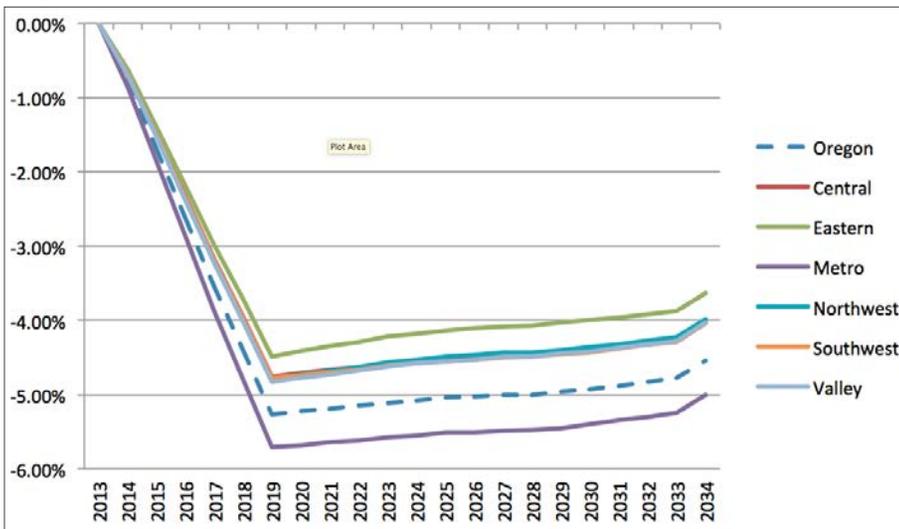
**Figure 13: Regional Percent Change in Residual Fuel Demand (\$30/ton CO2e)**



**Figure 14: Percent Change in Household Motor Fuel Demand (\$/ton CO2e)**



**Figure 15: Regional Percent Change in Household Motor Fuel Demand (\$30/ton CO2e)**



according to a weighted distribution of VMTs, this stimulus is spread throughout the state. The trucking industry experiences a modest increase in employment to meet the demand of the industries working on Oregon highways.<sup>18</sup> REMI model parameters (based on historical data) reflect a strong link between construction and demand for road transportation services. Figure 16 (on the following page) shows percent change in employment relative to the forecasted levels of employment in the industry.

Figure 17 (on the following page) shows the regional impacts on the trucking industry. The Metro region sees the smallest impact for two main reasons: the formula for disbursement of highway funds, and the impact of the tax on the broader Metro economy. The highway funds are disbursed according to a weighted measure of VMTs. The Metro region receives the largest portion of highway funds, but it is slightly less than what would be expected based just on VMTs. This means that the increase in road construction and maintenance activity is slightly weaker in the Metro Area. There are also more industries in the area negatively affected by the tax, decreasing demand for trucking.

## CONCLUSION

Initial data from British Columbia and the results of our forecasting in both studies agree that the implementation of a carbon tax would have significant impacts on the demand for transportation fuels. The higher energy prices due to the tax would incentivize behavioral change and fuel-reducing innovations, and increase demand for substitutes. While the use of carbon tax revenues would have an impact on the net effect of the tax, the existence of higher prices within the overall tax and repatriation scheme would ensure reductions in fuel demand.

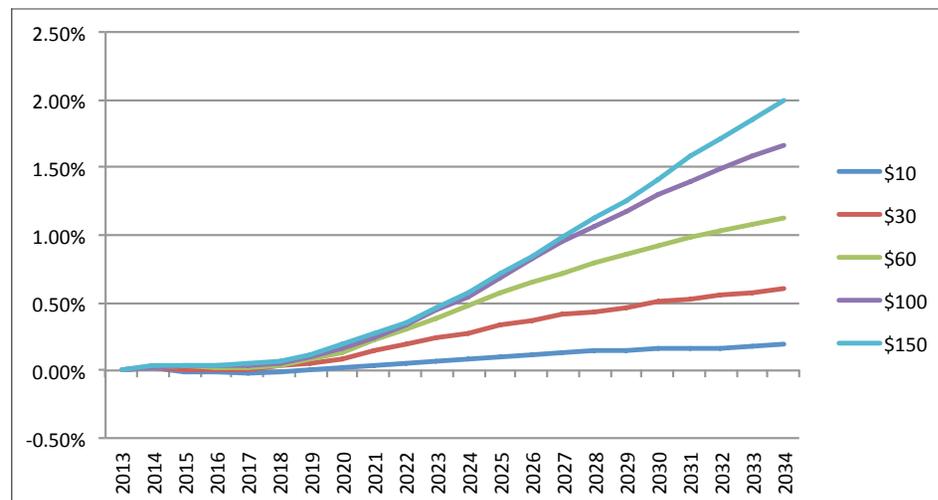
The research team ensured that the underlying economic and emissions models matched the current levels of employment, output, and emissions in Oregon. The underlying analysis which produced the results in this paper was informed by meetings with relevant stakeholders from business associations, utilities, community groups, government agencies, and environmental experts. The process was also informed by meetings with the SB306 Technical Advisory Committee, made up of representatives from state agencies with a connection to energy policy.

<sup>18</sup>Here, Truck Transportation employment refers to jobs with Oregon companies which transport goods by road.

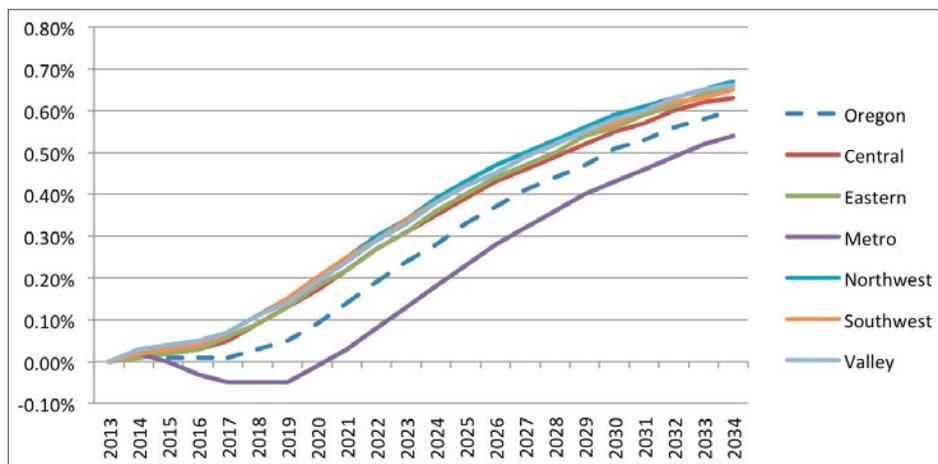
Because expected energy price changes due to the carbon tax were a basic input of the modeling, care was taken to estimate region-specific fuel price changes. Several utilities provided data which allowed the study team to create electricity generation fuel mix profiles for each region. As a result of the customization and dynamic interactions within the models, and the general agreement with early results from actual carbon pricing programs, the study team has a high level of confidence in the results.

The basic insight behind carbon pricing is not new, and is based in mainstream economic theory. If market interactions are leading to the overuse of resources outside of the market, imposing a price on the overused resource will bring it into the market and increase efficiency. Currently, the negative impacts associated with the release of carbon through fossil fuel combustion is not incorporated into the market. By imposing a price on carbon, fossil fuel consumers are incentivized to reduce their fuel usage. This reduction in fuel demand is not necessarily associated with lower economic output. In fact, depending on the use of the revenue, a carbon tax might lead to net increases in employment and output. Because of Oregon's constitutional requirements related to transportation fuel tax revenues, a tax on carbon would significantly increase highway funding in the state. This increase in funding would akin to a public stimulus project which would reach every region in Oregon.

**Figure 16: Percent Change in Oregon Truck Transportation Employment (\$/ton CO2e)**



**Figure 17: Regional Percent Change in Truck Transportation Employment (\$/ton CO2e)**



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# Appendix C: SRT Minutes

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF APRIL 8, 2014**

8:30 a.m. to 10:30 a.m.

DAS Executive Building, First Floor 155 Cottage Street N.E. Salem, Oregon  
97301-3966

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation  
Mazen Malik, Legislative Revenue Office  
Mike McArthur, Association of Oregon Counties  
Mark McMullen, Office of Economic Analysis (Chair)  
John Merriss, Independent Expert  
Tim Morgan, American Automobile Association of Oregon and Idaho Don  
Negri, Willamette University  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Craig Campbell, representing American Automobile Association of Oregon  
and Idaho  
Robert Maestre, Oregon Department of Transportation  
Lani Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Welcome, Introduction and Opening Remarks**

The meeting began at 8:30 a.m. and Mr. McMullen welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

### **Review of the SRT Meeting Schedule and Logistics**

Ms. Williams of DAS reviewed the proposed meeting schedule of the Study Review Team. It was agreed meetings will alternate between Salem and Portland. Meeting dates and times will be determined via Doodle polls. Ms. Williams proposed using DropBox as the file sharing system for the SRT and there were no objections.

### **Issue Papers**

Mr. Batten outlined the five issue papers mentioned in the Request for Proposals: (1) the outlook for fuel demand and the effectiveness of fuel taxes over the extended horizon; (2) the impact of carbon taxes on equity across road users; (3) a survey of recent cost allocation studies; (4) the Efficient Fee Technical Research Plan; (5) the Efficient Fee Technical Implementation Plan; and (6) a sixth issue paper of an “open topic” to be requested by the SRT.

(1) Regarding the outlook for fuel demand and the effectiveness of fuel taxes over the extended horizon, the American Association of Retired Persons (AARP) put out a paper last year summarizing the demographic contributions to these issues. The baby boom generation now approaching retirement is inclined to drive more often and longer distances than those older or younger than them. Mr. Batten added that there is an interaction between this paper and the one on carbon taxes. In Vancouver BC, where they have a carbon tax, vehicle miles of travel (VMT) decreased during the recession and remained there, while the rest of Canada’s VMT rebounded. Mr. McArthur asked whether the cost of fuel will be taken into consideration. Mr. Batten said yes and mentioned that consumers’ short- and long-term reactions to fuel price increases are different. For short-term spikes in gas prices, consumers may opt to shift miles to more fuel efficient vehicles within a household, while a long-term increase may cause them to acquire more fuel efficient vehicles. Mr. Morgan suggested a study of teen driver licensing

trends sponsored by AAA is relevant to the demographic issues and offered to send a copy to the group.

(2) Regarding the impact of carbon taxes on equity across road users, there are several other places that have already implemented a carbon tax and can give us useful information about how a carbon tax could work in Oregon. Oregon, Washington, and California are all sponsoring research to determine how a carbon tax policy could work for these states. Mr. Russell asked about a carbon tax study requested by the Legislature of Tom Potiowsky. Mr. McMullen said Mr. Malik is overseeing that study and asked if the findings could be leveraged for the SRT. Mr. Malik said the study, which was contracted with PSU and is extensive, looks at carbon taxes as replacing the existing revenue sources. Mr. Malik was unsure whether the HCAS issue paper would look at only portions of that study or at entirely different factors. Mr. Parrow asked how carbon taxes would feed into the highway fund. Mr. Batten said the 2011 Efficient Fee Study assumed the emissions fee would be imposed on a per gallon basis, as is the existing fuels tax. Mr. Russell pointed out that a carbon tax may be easy to avoid, particularly in the trucking industry. Mr. Negri said the prices between Oregon, Washington and California may not necessarily be that different, given the fuel taxes that already exist in Washington and California, but it's important to understand whether this will put a wedge between those two kinds of prices.

(3) For the survey of cost allocation studies, Mr. Batten said they will need to find all the most recent studies, including Nevada's and Idaho's. Ms. Pennington noted Virginia and Tennessee both conducted studies recently as well. Mr. Batten said Oregon's weight-mile tax is unique and prevents it from being directly comparable to other states. Mr. Negri pointed out that Oregon is likely the most progressive state with regard to these studies and he would like to see our studies receive more national attention. Mr. McMullen said several of our studies can be found on the OEA web site, but they can be difficult to find and are not advertised. It was generally agreed the studies should be made more available. Mr. Batten asked whether any ODOT economists participate in the Transportation Research Board, as that would be an excellent vehicle for gaining more exposure for Oregon. Mr. Merriss suggested

that during the research for this paper, the SRT consider lessons learned from other states and adopt improvements in methodology if any are found.

(4) Regarding the Efficient Fee Technical Research Plan, Mr. Batten said this could include the studies described in the 2011 Efficient Fee Study Report or the research plan could be focused on how the efficient fee method of highway cost allocation could be improved and implemented. What to accomplish with these two papers is the question before this group today. Mr. McMullen said the efficient fee paper from last time included next steps for a technical research plan and implementation plan, so his thoughts were to start with those steps. However, he added that Mr. Batten mentioned the research plan could be made more practical in terms of a policy pathway.

Mr. Batten said that while he isn't recommending this, it could be done as a more limited look focusing only on the HCAS rather than getting to efficient fees sometime in the future. Mr. Malik said he's not clear on the difference. Mr. Batten said one option is to do a paper on how HCA studies could be done using the methods of the 2011 Efficient Fee Study, but with improved data and methods. The other possibility is to say what data, analytical methods, studies, technology, actions, and political cooperation between agencies and the legislature would be necessary to actually achieve a state where efficient fees are being charged. What it would take in terms of resources, dollars, new technologies; lay out all the steps, a detailed blueprint. Mr. Russell said that was the intent of the paper last time and asked why a different result would be expected this time. Mr. Batten said if they weren't looking at the question just described, then the scope of these papers would be much more limited. The SRT wouldn't be talking about how efficient fees could be achieved, but rather how to replicate efficient fees within a HCA study.

Mr. Russell said if we were to do the two papers listed, he does not believe the legislature would have much interest in them. He said it needs to be more of a policy paper than a technical paper for the legislature to engage. It was asked whether a blueprint would help the legislature engage in the steps and Mr. Russell said yes, they would see a role for themselves and would be able to determine whether that path is worth pursuing. Ms. Bohard suggested a need to agree on the

purpose of the paper before it goes too far. She suggested thinking about the blueprint currently in place and what is missing to support efficient fees. The team needs to understand the barriers and how large they are because until then the group doesn't know what it's asking.

Mr. Parrow asked about Jim Whitty and how his effort interfaces with the HCAS, since one of the necessary components of an efficient fee approach is VMT. Mr. Maestre said most of that would probably have to come in a variable fee structure. Right now the VMT fee is viewed as a flat charge per mile, but an efficient fee would also deal with time and place variability. It was asked how externalities are priced; if there were an efficient fee and we were charging for air quality, where would that money go and how would that work? That's the question because that comes into the construct of the constitutional restrictions and there are only a certain amount of things you can do in highway construction that reduce air and noise pollution. Does sending a price signal alone accomplish the goal or do you then need to take the money and spend it on different things than you spend it on today? The economists would say the price signal alone can solve the problem. It will set the optimal level of consumption, and what you then do with the money is a separate question. Reserves are created so when you run out of capacity you can increase it. Ms. Bohard said Mr. Whitty's effort next year will be on logistics and mechanics. Mr. Malik said there shouldn't be any contradiction between VMT fees, what Mr. Whitty is doing, and efficient fees. They could work together or independently. If Mr. Whitty solves the logistics problem, then the fees become variable and this becomes simpler.

Mr. Campbell said AAA has concerns about how variable taxes are applied because it has a disproportionate impact on their members. They would like to know what the realm is, but once the SRT gets to that discussion, AAA will raise their concerns at that time. Mr. Negri asked if there is consensus the group would like a blueprint paper. He added that Mr. Batten could bring an outline of what that would look like to the next meeting and the SRT could then debate whether those pieces meet its needs. He also asked for the final version of last biennium's paper so the group can review what it did and what is still needed. Mr. Batten asked the members to submit a one-paragraph problem statement of

what the paper should be about. Mr. McMullen said part of the problem last time was the broadness of the scope for the paper.

(5) With respect to the Efficient Fee Technical Implementation Plan paper, Mr. Batten said the research paper is needed before implementation can be described in any detail. It would be a fairly large research effort to gather all the current state of the art information and lay the foundation to develop an implementation plan. The implementation plan paper was envisioned as a large, multi-agency effort involving a lot of policy work, so the first study is to characterize what an efficient fee would really look like and what costs would go into that, and the second piece is how to get from where we are to where we should be. It's also important to look at the options and what's been done in other places, what's known about the available technologies and where they're headed. Ms. Bohard said she wasn't sure the number of papers makes a difference. The idea of what's in the RFP is the level of effort we expect in the research. She agreed that each SRT member should write a paragraph on what the paper should be.

Mr. Parrow said he would like to discuss this further at the next meeting after everyone has had an opportunity to look at the previous paper. He also suggested reviewing the comments received last time to better understand what the concerns were. Mr. McMullen said he would find the thread of comments and the final paper and place those in the Drop Box. Mr. Merriss suggested reviewing the previous paper and comparing it against the final version of the outline in order to know whether the outline was satisfied, since it could be the outline from before isn't what people really want to see this time. Mr. Batten said if the implementation plan is for efficient fees, he doesn't believe even when the paper is complete that ODOT would be ready to undertake a real technical implementation as it would require a variety of engineers and people with more expertise than ECONorthwest can provide. Mr. McMullen said that since efficient fees are an inevitable component, it seems like at least having a small section describing implementation would be worthwhile so the legislature knows where we are in the development. Whether there is one paper or two will need to be determined after the outline is produced.

(6) For the open topic paper, Mr. Russell asked about the potential of averaging the study results over a period longer than a biennium to preclude spikes and aberrations from affecting the tax rates. Mr. Merriss said he wasn't sure if it's that important anymore because the results of the last several studies have been quite similar. Mr. Batten said a moving average could be calculated after the fact. Mr. Russell asked about the best way of doing that and suggested an issue paper would be helpful for the SRT. If the Columbia River Crossing project had moved forward it could have produced a spike having a potential impact on tax rates, and Oregon may be in the same position with federal funding. Mr. Maestre said that kind of paper would have two parts: defining an aberration and explaining what the recommendation would be if it occurred. Mr. McMullen said the question is to what extent the expenditures in the two-year window the SRT examines reflect longer-term highway expenditures. A reason for smoothing is to base the study results on the longer-term highway needs over ten or twenty years rather than what is being built today. Mr. Batten said part of this is taken care of with bond financing. Mr. Russell said some policy choices have been made – for example, subsidized vehicles are now being dealt with in a different way. When choices like that are made, there is the potential of impacting tax rates and it would be nice to have a way of smoothing that out. Mr. McArthur suggested thinking about implementing an approach that looks at five-year windows rather than biennia and report it as a running average and not as a point in time. Mr. Russell said he could think of a number of ways to approach this, but a white paper could help determine the best way. Mr. Batten asked about changes in the HCAS methodology versus how revenues are collected or how ODOT spends money. Mr. Russell said maybe that should also be part of the paper.

Mr. Merriss liked Mr. Russell's suggestion, but would also like to see a paper dealing with the allocation methodology itself and suggested studded tires would be a good topic since that has been one of the weakest part of the study. Mr. Batten said a paper could be done on the best way to incorporate ODOT's upcoming studded tire research findings. Mr. Russell liked the idea of including this with the topic of averaging because that is a good example of where updated information could have an impact. Mr. Campbell said the challenge

with studded tires is that money isn't necessarily spent to repair all the damage done by them.

Mr. McMullen suggested summarizing this as twenty years of HCAS: methodology, volatility of results, weaknesses, and future enhancements. Mr. Merriss said that is pretty broad. Mr. Russell said there are always pieces that could result in an aberration and that could be discussed in a paper, but the important part is to determine the best way of dealing with an aberration to smooth the curve. Mr. Malik said Mr. Russell would like a sensitivity analysis and to determine the sort of changes that would cause the SRT to recommend a rate change to the legislature as opposed to those changes that would balance themselves out. Mr. Maestre said Mr. McMullen's description of volatility in the HCAS is the perfect framing phrase because it captures what could be going on in the short term to make the HCAS results volatile, aberrations over the next two to five or ten years that could dramatically affect the HCAS results, and what the state's response should be to that volatility. Mr. Campbell asked what a paper about studded tires would include. Mr. Batten said that in the past it was decided that studded tire costs couldn't be directly applied because ODOT doesn't actually spend that much money on these repairs. Mr. Campbell said he doesn't know how any data besides the expenditures could be used without drastically changing the way the study is done. The issue is whether ODOT, as a policy outside the HCAS, should be spending more money on studded tire damage repairs and should collect a tax from those who cause the damage. Mr. McArthur asked whether there has been a recent look at the relative impact of vehicles weighing 6,000 lbs. versus 20,000 lbs. Mr. Batten said the curve-fitting pavement damage model does go all the way down to basic vehicles and there is a difference between a 12,000 lb. vehicle and a 6,000 lb. vehicle.

Regarding the report to the legislature, Mr. Batten suggested the SRT establish rules in advance for deciding on which figures to base its recommendations, then remind the legislature of prior studies and explain the moving average. Mr. Maestre summarized that ECONorthwest will write a paper with the SRT's help explaining, "This is when figures go up and down, these are the variables that could move dramatically, and we would recommend that the legislature change rates when...." He then asked under what circumstances the SRT recommend

that the legislature make a revenue neutral change in rates when we aren't planning on changing them otherwise? Mr. Malik said there will be criteria if it's above a certain percent or a result of one type of change versus another type of change. He added that if the studded tire study results aren't available until November, then it may not be possible to include them in this paper. It may be a topic for a more detailed discussion in the next study. Ms. Bohard offered to have Norris Shippen and Michael Bufalino attend a future SRT meeting to provide the group with an idea of what they're doing and the timeline.

Mr. McArthur said the group should discuss how it will calculate the equity numbers this time with regard to studded tires and to what extent the information that may be under development affects our calculation of the equity ratios. He believes it would be better to determine how the SRT makes its recommendations rather than whether it thinks the information on studded tires is going to affect the way the equity calculation is done now or in the future. Mr. Russell said the last study on studded tires was done in 2000. If the studies were done regularly there wouldn't be the aberration in rates, so that needs to be taken into consideration. Mr. McMullen said it doesn't have a huge impact on the HCAS results, but the legislature is still interested in it. Mr. Merriss said Mr. Malik's studded tire study contained two annual numbers, the first the true total economic cost of studded tire damage (approximately \$42 million), and the second the number used in the study which was the estimated expenditure to mitigate studded tire damage (approximately \$7 million for state highways). The higher number would be used in an efficient fee type of cost allocation study. Mr. Negri asked how the data is gathered. Ms. Pennington said there is a survey underway currently collecting that information.

#### **HCAS Model Data Collections Efforts**

Mr. Batten said the data collection plan is the same as for the previous study, although Portland State will be used as a subcontractor. PSU is collecting data from ODOT through its portal system. Mr. Russell asked whether Ms. Pennington is going to be in charge from ODOT's perspective to monitor the quality. Ms. Pennington said the last time she spoke with PSU they were collecting the data on a regular basis. Mr. Batten said ODOT collects the truck weight data through its weigh-in-motion devices

and shares a copy with PSU. Mr. Russell asked to be informed if there are any changes in how the data is collected. Ms. Pennington said it is being done the same way as in the last couple studies.

Ms. Bohard asked Mr. Batten if he is prepared with the revenue and budget information. Ms. Pennington said all the information should be available by August. Mr. Malik said the average vehicle miles per gallon (MPG) numbers are national estimates and asked whether more Oregon-specific data could be obtained. Ms. Bohard said she would look into that. Mr. Batten said Dave Kavanaugh uses an assumption about vehicle MPG in his revenue forecasting model. He comes up with the VMT and a budgeted amount of fuels tax collection, which are put into the highway cost allocation model along with a light vehicle MPG estimate as a starting point. The model then iterates to determine the light vehicle MPG needed to cause the forecasted VMT by light, medium, and fuel-tax paying heavy vehicles to produce the revenue that ODOT says will be produced, given MPG by weight class assumptions for medium and heavy vehicles.

Mr. Malik said the lynch pin is that national data is being used as the starting point. He asked if there could be a better specification by using Oregon-specific data, since Oregon and the nation appear to be diverging. Mr. Batten said Dave Kavanaugh usually makes a presentation to the SRT, and Ms. Pennington said it is on the schedule for August or September. Mr. Batten said another important item is to get the VMT forecast and budget forecast from the same time period. Ms. Pennington said last December's forecast would be used for both the VMT and budget forecasts. Mr. Batten said if a new budget comes out before the study is complete, then the study can always be updated.

#### **Action Points**

- SRT members will submit brief problem statements describing what they would like the efficient fee paper(s) to address. Mr. Batten will use these to develop an outline (or outlines) to discuss at the next meeting.
- Ms. Bohard will arrange for Norris Shippen and Michael Bufalino to attend the August SRT meeting to discuss the studded tire study currently underway.

- Ms. Williams will invite the SRT to the Drop Box account where study documents will be stored, including the efficient fee materials from the last study.
- A Doodle poll will be sent out to assist with scheduling the next SRT meeting.
- Ms. Williams will send a reminder request for the SRT's problem statements for the scope of the efficient fee issue paper, which will be due to her by April 25.

Meeting adjourned: 10:22 am.

The next meeting will be held in June on a date to be determined at 222 SW Columbia St., Suite 1600, Portland, Oregon 97201.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF JUNE 23, 2014**

10:00 a.m. to 12:00 p.m.

ECONorthwest Offices 222 SW Columbia, Suite 1600 Portland, Oregon 97201

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation

Mazen Malik, Legislative Revenue Office

Mike McArthur, Association of Oregon Counties

Mark McMullen, Office of Economic Analysis (Chair, via phone) John

Merriss, Independent Expert

Don Negri, Willamette University

Doug Parrow, Independent Expert

Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest

Craig Campbell, representing AAA Oregon/Idaho

Josh Lehner, Office of Economic Analysis

Robert Maestre, Oregon Department of Transportation

Lani Pennington, Oregon Department of Transportation

Jeff Renfro, Northwest Economic Research Center

Amy Williams, Oregon Department of Administrative Services

### **Approval of the April 8, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 10:05 a.m. The minutes from the April 8 meeting were submitted for approval. One small edit was made, after which the minutes were approved.

### **Efficient Fee Issue Paper(s)**

During the April, 2014 SRT meeting it was agreed the team would submit problem statements describing what each member felt the Efficient Fee paper should encompass. The group agreed issues relating to data availability would be essential. It was also agreed that if the paper is to be presented to the Legislature, it would need to include a historical perspective in order to provide context. It was suggested the research paper could be done now, but the technical implementation plan should wait until implementation is imminent so that all available technologies can be considered.

ODOT is in the process of working on a program for VMT. It was suggested the SRT should be part of that discussion in order to have the ideas behind an efficient fee considered. It was thought the only way an efficient fee model could work is if a GPS capability is attached to it and required. However, this idea likely would not get traction in the Legislature.

It would be necessary to have very accurate calculations of efficient fees in order for such fees to be accepted by consumers. However, there is a cost to collecting, storing, and analyzing the data, and that also needs to be taken into consideration.

Regarding the assessment of fees, it was observed that consumers now have real-time maps of traffic congestion available on their cell phones, so could a congestion-based charge take advantage of that? It would need to be predictable so people would know in advance if they were heading into a high-cost zone versus having it turn into a high-cost zone while they're in it with no way to avoid the cost. A system would be needed to excuse people from paying high tolls if an incident is causing the congestion rather than just the volume of cars. Some of the managed lane systems provide a guaranteed price to different destinations so when the gantry is passed the driver receives the price that's in effect at that time. A simplistic system would be to change the cost based on the time of day. During rush hours it costs x, during non-rush hours y, and at night z.

Understanding the implications of traffic diversion is extremely important. If a driver knows he/she is going to be charged for driving on I-5, that driver might elect to stay off I-5 and instead travel on adjacent, non-tolled roads. From a congestion standpoint on the tolled road that may work, but from a neighborhood and public relations standpoint it can result in a whole different outcome.

The efficient fee plan has three distinct phases. Phase one includes the research plan, in which data is collected and analyzed and emerging technologies researched. Phase two is the technical implementation plan, which would involve systems design, engineering, specifications, application programming interfaces, etc. Phase three is the organizational implementation plan, specifying the roles and responsibilities of commissions, state and federal agencies, contractors, local governments, etc. This plan would also describe funding sources for implementation and how efficient fee revenues would be collected and disbursed.

It was suggested this be presented to the Legislature in 2015 or 2017, with the intent being that it result in legislation authorizing a pilot project. The SRT determined the research paper should address the following questions:

- What needs to be known in order to begin designing a pilot?
  - Available technologies
    - Data that would need to be collected
    - How to measure congestion
    - Which externalities to include (greenhouse gases may be worth considering because if a carbon tax were to be implemented, it could affect the rest of the efficient fees)
    - Governance (who sets policy at what level and what type of policy)
      - Local vs. state roads and where the funds go (a fee only on state roads would shift drivers onto local roads; possible subsidization)
      - Federal regulations
- Why should the Legislature want to do a pilot?
- If the Legislature decides to proceed, what does it need to do?

It was agreed the paper needs to bring the team to an efficient fee plan that might be politically possible when presented to the Legislature. It should not make recommendations, but point out the strengths and weaknesses of the technology and what some of the hurdles might be. The paper

should review/discuss the extensive work ODOT has completed on tolling and pricing. There will be a preliminary discussion of the draft efficient fee paper at the HCAS meeting in September and further discussion at the October meeting, with the final version produced later in the process. An outline will be provided to the SRT in advance of August's meeting to "check in" and ensure the SRT agrees with the direction.

### **Preliminary Draft of Issue Paper on Carbon Taxes**

This issue paper will be in four parts. The first part will look at transportation-related issues surrounding the British Columbia (B.C.) carbon tax. The second part will focus on transportation-related issues for other carbon pricing schemes around the world, particularly the Irish example. Last year the Northwest Economic Research Center wrote a report called "Carbon Tax and Shift" in which the effect on the economy and on emissions of implementing a B.C.-style carbon tax in Oregon were analyzed. From that report the transportation-specific issues are being pulled out and presented in the issue paper.

B.C. established a carbon tax in 2008, intending it to be revenue-neutral. The tax is applied on volumes of fuel. If a gallon of gasoline is purchased, it's assumed the combustion of that gallon will produce a certain amount of greenhouse gases. The consumer then pays a little more for that gallon of gas based on the established carbon price.

B.C. intended to return all the revenue from the tax, mainly through cuts to corporate income and personal income taxes. There are a few other programs that offset the negative effects for low-income households and rural residents, and there is also a farm property tax cut. However, the program ended up being slightly revenue negative because too much money has been rebated. B.C. calculates the amount of rebate before actually collecting the revenue, so it's based on a forecast.

While it's too early to isolate the effects of the tax, B.C. officials say their Gross Domestic Product is growing slightly faster than in the rest of Canada. Emissions are also falling faster than in the rest of Canada and gasoline use has declined, so they call it a success. However, during this same time frame the government invested in public transportation so people have more options, and between that and the limited number of years since implementation, it's hard to point to the true effect of the tax.

It is even more difficult to isolate the effects of the tax in Ireland because their recession was extremely severe. The tax was implemented in part just to generate revenue. They have seen reductions in the sale of motor gasoline, but at the same time they implemented the tax they also changed all vehicle fees and gasoline taxes, and there are even fewer years to analyze. The tax is generating revenue, and studies have said the negative economic effects associated with the tax have been minimal to non-existent, so at this point they think it's successful and will continue the tax.

South Africa just delayed the implementation of its tax until 2016, and Australia has a new government so their tax is probably dead. They had been ready to be the second big economy to implement an economy-wide comprehensive carbon tax. Several Scandinavian countries use a carbon tax, but they tend to be limited in their application, and in addition there are some broader economic issues related to the energy sector that make it hard to draw any lessons for Oregon. As a result, the focus of the paper will likely be only B.C. and Ireland.

The methodology of the report starts with the Energy Information Administration's (EIA's) forecast for energy usage and price, and then takes the Pacific region's forecast and puts it in the model to implement a carbon price. It alters the price forecast for each of the different types of fuels tracked. That change of price is passed through elasticities, with the result being a new consumption level for each of the different fuel types. Based on that new consumption level, the revenue associated with usage of that fuel can be calculated along with the change in emissions from the expected baseline.

The paper will incorporate the fact that in Oregon any tax revenue associated with transportation fuels has to go into the Highway Trust Fund. Legislative Counsel's opinion is that under the constitutional construct, the use of carbon tax revenue could not be changed unless the constitutional language was changed. However, the study will look at how investing within the entire transportation sector, rather than only highways, might be possible. Revenue neutrality could be achieved by using a reduction in registration fees to repatriate a portion of the proceeds from a carbon tax, thereby keeping everything within the world of highway funds.

The original study was very constrained and had to work with EIA's four extremely broad economic sectors. The new study will start with EIA's energy price forecast and take those prices as its baseline, but then apply a carbon tax to each of the different fuels to get a percent change in the price for each. Each sector reacts differently to energy price changes, so then there is a new level of output for each of those industries. The research group is working with two physicists at Portland State University who will calculate emissions factors associated with each of these industries in each of the six Oregon regions being examined. Based on the change in economic activity there will be a change in fuel use, and that will be used to calculate the change in revenue associated with the tax. That revenue is put back into the model to estimate the different repatriation scenarios being examined.

Following B.C., a big part of every scenario will include cuts to personal and corporate income tax rates, but broader scenarios are also being considered. If this is an environmental policy, it makes sense to reinvest some of the tax revenue in measures that will further reduce greenhouse gases. Senate Bill 306 requires a focus on the effects on industries defined by Business Oregon, so there will be a scenario in which those industries are exempt from the tax. Each of the scenarios will have information about effects on employment, output, and wages, and that will be broken out for each of the six Oregon regions. Then the 70 industries in each of these regions can be analyzed rather than the four super- aggregated sectors from before. Different transportation industries will increase their costs due to the tax, which means other industries will have to deal with higher prices for transportation.

It was pointed out that while both B.C. and Ireland claim their economy did not suffer after the implementation of a carbon tax, both economies have gone under fundamentally different business cycles in the last five years. Western Canada has had an oil boom, a natural resource boom, and a housing boom, while Ireland is in a full economic depression. The effects of a carbon tax can't be accurately analyzed right now in either economy. Legislators might conclude a carbon tax didn't hurt B.C.'s economy and attribute Ireland's issues to its depression, but neither of these may be accurate conclusions. Providing the Legislature with these two examples may therefore be problematic.

### **Model Flowchart**

The model flowchart represents no change in the way the model works or the process for manipulating the data and coming to an answer; however, some changes will be made to the way the model is constructed mechanically. Currently there is a computation module called by Visual Basic inside of Excel, which passes data back and forth. This will be altered so there is one workbook with multiple tabs containing only input data for the model. The model will then pull the data out of that workbook, do its manipulation, and then fill up another workbook that is only outputs. It would presumably be a little easier to use and to find specific items. The model should be ready for auditing sometime in September.

### **Draft of Issue Paper on Recent Cost Allocation Studies**

Only one state has issued a new HCAS report since the SRT last did a review of studies from other states and that was the state of Idaho in 2010; however, the University of Minnesota conducted a study for MNDOT, which was published in 2012, and will be included in the Issue Paper under discussion. The SRT was provided with these two studies, in addition to one from Nevada which had been reviewed already by the SRT during a previous cost allocation study. The draft paper on Recent Cost Allocation Studies will be sent to the SRT via email and discussed at a future SRT meeting only if something controversial comes out of it.

Meeting adjourned: 11:58 am.

The next meeting will be held on August 14, 2014, at the DAS Executive Building, located at 155 Cottage Street NE in Salem, Oregon.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF AUGUST 14, 2014**

2:00 p.m. to 4:00 p.m.

DAS Executive Building 155 Cottage Street N.E. Salem, Oregon  
97301-3966

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation  
Mazen Malik, Legislative Revenue Office  
Mary Stern for Mike McArthur, Association of Oregon Counties Mark  
McMullen, Office of Economic Analysis (Chair)  
John Merriss, Independent Expert  
Tim Morgan, AAA Oregon/Idaho  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Craig Campbell, representing AAA Oregon/Idaho  
Erin Haswell, ECONorthwest  
Dave Kavanaugh, Oregon Department of Transportation Robert Maestre,  
Oregon Department of Transportation  
Lani Pennington, Oregon Department of Transportation  
Dave Ringeisen, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the June 23, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 2:00 p.m. The minutes from the June 23 meeting were submitted for approval. One small edit was made, after which the minutes were approved.

### **Traffic Data Collection Presentation**

Dave Ringeisen of the Oregon Department of Transportation (ODOT) presented the department's traffic data collection methodologies and procedures. The data collected is used for planning, design, construction, operations, and maintenance decisions. ODOT has 178 Automatic Traffic Recorders (ATRs) in the state, in addition to 22 Weigh-in-Motion sites and approximately 300 ramp metering sites. Depending on the type of ATR being used at a particular location, data such as traffic volume and speed, and vehicle length and classification can be recorded.

There are 8,200 total count sites in Oregon, including both permanent and short-term (temporary) sites on State highways and non-State (county, city, and federal) roads. Most of these sites collect count data only, although some 20% also record vehicle classification. The statistical methods used follow national standards, as well as being based on Federal Highway Administration and American Association of State Highway and Transportation Officials Best Practices. The data is reviewed and certified annually by the Federal Highway Administration.

To conduct counts with the federally-required vehicle classifications, ODOT places video cameras at traffic count locations for 24 hours at a time. These video classification counts are conducted at approximately 385 locations per year around the state. ODOT personnel view the videos and classify the vehicles into 13 classes. This is part of a federal requirement to report the classifications of vehicles going across these sites. This reporting is done on a three-year cycle and these counts appear in the federal VMT reports.

### **VMT and Fuel Tax Revenue Forecasts Presentation**

Dave Kavanaugh maintains and updates the revenue forecasting model for ODOT and presented on the Vehicle Miles Traveled (VMT) and fuel tax revenue forecasts. The fuels-based method for VMT estimation classifies vehicles as light (up to 10,000 pounds gross weight), medium-heavy (10,001 to 26,000 pounds gross weight), or heavy (over 26,000 pounds gross weight).

Adjustments are made for off-road fuel consumption (e.g., farm use). An adjustment is also made for the so-called “Clark County effect” – the net of fuel purchased out of state but used on Oregon roads versus fuel purchased in Oregon but used out of state. For heavy vehicles, their reported miles are used, since trucking companies are required to submit this information when they file weight- mile taxes. Adjustments are made for estimated tax evasion. The assumed fuel efficiency of the light-vehicle fleet is from a nationwide estimate. The relative shares of statewide VMT (2010-13 averages) are 92.5% for light vehicles, 2.3% for medium-heavy vehicles, and 5.2% for heavy vehicles.

The current statewide VMT forecast shows growth of approximately 2.2% annually until mid-2015, followed by slightly-decreasing growth, leveling off at approximately 1.5% growth by 2019. An earlier (2012) forecast by Dr. Kavanaugh was compared against his most recent (2014) forecast. The new forecast shows VMT growth to be significantly slower than had been projected two years ago, this attributable primarily to the unexpectedly sluggish economy.

The average age of cars in the light-vehicle fleet is expected to continue to increase, slowing the rate at which improvements in new-car fuel economy affect the fleet-wide average. The average age is currently 11.4 years and increasing at a rate of 1.4% per year, while the average age of light trucks is 11.3 years and is increasing at 1.7% per year. Consumers are keeping their vehicles longer due to rising sticker prices on new vehicles and quality improvements which make existing vehicles last longer without requiring major repairs.

The annual compound rate of improvement in light vehicle fuel efficiency between 1980 and 2013 was 1.14%; between 1990 and 2013 0.4%; and between 2003 and 2013 0.32%. Motor vehicle fuels growth was negative in 2011 and 2012, but is expected to grow steadily through 2015 by up to 3% annually. After this, growth in fuel consumption is predicted to slow and level off by 2018 at around 1.25% annually.

It was asked how the various VMT estimates, including those from the Highway Performance Monitoring System (HPMS), relate to the revenue forecast which is based on economic factors. Dr. Kavanaugh said they are linked by the physical quantity of gallons. The gallons used in the fuels-based VMT forecast are the same as those used in ODOT's revenue

forecast. If the fuel efficiency of vehicles can be assumed, that assumption can be applied to the forecasted gallons by light and medium-heavy vehicles in order to come up with an implied VMT by those vehicles.

The forecast of VMT by light, medium-heavy, and heavy vehicles used in the HCAS is ODOT's forecast, since this is the forecast driving the budgeted amounts used for spending and revenue. While the HCAS will consider forecast discrepancies between ODOT's revenue forecast and the HPMS, it will use ODOT's forecast.

A change is occurring in people's behavior with the purchase of electric, hybrid, and other higher Miles per Gallon (MPG) vehicles. This could cause gas tax revenues to decrease even while the VMT is going up. It was asked how to change cost responsibility to reflect these changes. The MPG assumption would need to change, which means the VMT would also need to change because the number of gallons (VMT/MPG) is what is measured and forecasted. It was suggested the model could be turned around to use an external assumption of MPG for light vehicles, yet still remain consistent with the budget and forecasted revenue. VMT would then be calibrated rather than MPG, and this calibrated VMT could be used in the model to allocate costs.

Currently gas tax revenues are relatively easy to predict because gasoline is taxed at the wholesale level. If a road user fee is put in place, a proxy for the average cost per mile will need to be used and if that is incorrect there could be problems. The Legislature may look to the HCAS to set that number initially, so the SRT needs to be sure it can defend the number.

The revenue model is predicted off actual gallons sold, so the resulting VMT from the model depends on the MPG assumption being correct. If there were a potentially better, more Oregon-specific estimate of MPG, then the forecasted gallons could be used to adjust the VMT forecast. It was suggested time be spent at a future meeting to discuss alternative outlooks for fuel efficiency and VMT.

It was asked whether any work is being done to use the HPMS data in a different way for estimating VMT. Dr. Kavanaugh said there is not and that the federal government is trying to enforce the number of counts done within certain areas to ensure the national statistical model. Mr. Batten said the HPMS data is used in the HCAS model for the purpose of taking the estimates of VMT and spreading them over the functional road classes.

### **Outline of Issue Paper on Outlook for Fuel Demand**

The SRT reviewed the issue paper outline in addition to two charts, one showing U.S. VMT and gallons taxed from 1980 to 2012, and the other showing VMT and per-capita VMT in Oregon from 1980 to 2012. The Oregon VMT in the chart is from the HPMS.

The per capita VMT increase through 1999 was primarily due to increased workforce participation, longer trips, and increased auto mode share. The decline since 1999 could be due to several factors, including the oldest baby boomers beginning to retire; the millennial generation being less enchanted with the idea of driving and more likely to live in urban areas; transit service improving; and online shopping becoming more available and widely used. The rapid decline of per capita VMT may be over, however, with a continued, slower decline due to urbanization, land use policy and greenhouse gas policy likely. As the population continues to grow, it may balance out the per capita decrease and hold VMT relatively steady, though it will likely continue to fluctuate with the economy.

It was suggested the CAFE standards be included in the paper. It was asked whether the paper will discuss future changes in VMT for heavy trucks and the freight industry. Mr. Batten agreed it was valid, but pointed out that there is less uncertainty about the future of heavy vehicle miles of travel. The purpose of the issue paper is to look at the long-term future of overall VMT and fuel tax revenue and what it means for Oregon's long-term choice of tax incentives. It was suggested a final point be added to the paper to tie the topic back to highway cost allocation and how to account for it in the study.

### **Outline of Issue Paper on Efficient Fees**

This outline reflects the SRT's efficient fee brainstorming activity during the meeting in June. It was suggested the paper begin with the background on efficient fees and conclude by outlining what the Legislature would need to do should it wish to proceed in authorizing a pilot project.

It was asked how efficient fees would differ between rural and urban areas. Mr. Batten said people in urban areas would likely pay more to the extent that those are the people who use congested roadways the most. Part of the economic theory behind pricing is that the places where the prices are high are a signal this is where the money should be spent. If the people in Portland feel they need more highway capacity, the system would be

raising the right amount of money and signaling where it should be spent which, in the long run, would solve the problem. It was suggested the entire transportation system should be considered. Theoretically, \$1 billion in extra revenue could be raised through an efficient pricing mechanism with not a dime of that spent on roads, but there could still be a significantly improved transportation system.

Least cost planning also needs to be considered. Once the location is determined for where additional capacity is needed, least cost planning would pick the least cost mode to address that transportation need. Efficient fees determine the need and who pays for it, but how the need is addressed falls under least cost planning. However, the ability of least cost planning to make those decisions is somewhat limited by the constitutional requirement that highway fund revenues be spent on highways. It was observed that many things could be done to improve alternative modes of transportation within the highway right-of-way. Examples include using highway funds to pay for such things as bus pull-outs and better pedestrian and bike facilities. It was also noted that the Constitution could be changed to make the highway fund into a transportation fund.

Mr. Batten pointed out that there is some important information that wouldn't be obtained in a pilot, namely how people would respond if everyone were paying efficient fees. Even if participants changed their behavior during the pilot, it wouldn't change overall congestion very much, so the participants would not reap the benefits that would accrue if everyone participated.

In an experiment the Puget Sound Regional Council conducted on pricing, participants were recruited using a protocol designed to get a representative mix of people rather than relying entirely on volunteers. People who were invited could decline, but volunteers couldn't join unless they were invited. An endowment was given to participants which was designed to be slightly more than what they would be charged if they maintained their established behavior, but if they changed their driving behavior they would receive additional money at the end of the study.

The next meeting will be held at 10:00 am on September 9, 2014, at the ECONorthwest offices at 222 SW Columbia Street, Suite 1600, Portland, Oregon. The VMT issue paper will be moved to the top of the agenda for that meeting.

Meeting adjourned: 3:55 pm.

**OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM  
MEETING MINUTES OF SEPTEMBER 9, 2014**

10:00 a.m. to 12:00 p.m.

ECONorthwest Offices 222 SW Columbia, Suite 1600 Portland, Oregon  
97201

Attendees:

**Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation

Mazen Malik, Legislative Revenue Office

Josh Lehner for Mark McMullen, Office of Economic Analysis (Chair) John

Merriss, Independent Expert

Don Negri, Willamette University

Bob Russell, Oregon Trucking Associations

**Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest

Craig Campbell, representing AAA Oregon/Idaho

Erin Haswell, ECONorthwest

Matthew Kitchen, ECONorthwest

Lani Pennington, Oregon Department of Transportation

Amy Williams, Oregon Department of Administrative Services

**Approval of the August 14, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 10:00 a.m. The minutes from the August 14 meeting received unanimous approval.

**Draft Issue Paper on Recent Studies from Other States**

Overall, the paper received positive feedback. It was suggested it would benefit by showing the contrast between Oregon's methodology versus other states', perhaps listed as bulleted items. In addition, an explanation of how and why Oregon does its studies the way it does would assist readers who are not as familiar with the HCAS procedures.

**Preliminary Draft of Efficient Fee Research Paper**

The primary author of this paper, Matthew Kitchen with ECONorthwest, has experience managing an instrumented vehicle pilot project on variable charging in Seattle. This provided a valuable perspective to the paper and, in general, it was felt this paper was a vast improvement over the efficient fee paper produced for the 2013 Study.

The preliminary draft does not explain why a demonstration project is needed or which missing data points are needed to move forward and whether the existing Oregon data is usable. Legislators want a way to adequately fund the transportation system that is immune from political influence. An efficient fee system would set money aside and include a rational way (using, for example, least cost planning) to choose the next project. That would be attractive to policy makers. Jim Whitty has a pilot scheduled for July of 2015 and the efficient fee pilot could build from it, but this is not made clear in the paper.

It was observed that one of the benefits that could be made more explicit in the paper is the personal time individuals would recover under an efficient fee system. Individuals who commute on those roads presently most congested, i.e., the metropolitan freeways, might expect an average of 30 to 45 minutes per day in time savings, while those commuting during peak times might receive as much as 60 to 90 minutes per day. This is something that would resonate with legislators and the public.

Other benefits could be packaged with an efficient fee system to make it more attractive, such as automatic re-registering of vehicles at the DMV. It also needs to be stressed that consumers traveling at uncongested times

would pay a lower rate. Policy makers have gravitated toward the idea of an efficient fee because it would set aside money for future expansion rather than having to fund projects in a piecemeal fashion. An efficient fee system would also cover almost all the costs of improving the transportation system rather than just the wear and tear on the highways.

An incremental implementation could begin with a flat fee measured with an onboard unit capable of also calculating variable fees. If the system then progresses to variable fees, ubiquitous dynamic pricing could be done at a lower cost than the expensive approach many states are using in which they place transponders in cars and gantries over freeways.

Some members of the SRT felt emissions fees for air, water or noise pollution could be difficult to sell to the Legislature and general public. Others, however, said transportation and the environment are intertwined and both will need to be addressed in order to get enough critical mass for an efficient fee system. It was observed that once the congestion externality begins to be eliminated, progress will have already been made toward eliminating some of the environmental externalities.

Oregon previously did a series of papers on tolling for greenhouse gas emissions, but none is cited in the present draft paper. With appropriate changes to Oregon's Constitution, a per-mile fee could be charged for congestion and wear and tear, while emissions could be covered with a carbon fuel tax.

During Mr. Kitchen's pilot project work in Seattle, the participants understood that variable fees produce considerable revenue and they wanted to know what would be done with the revenue. The revenue opportunities are significantly larger than the benefits to the users, so something people value must be done with the funds or else everyone may be worse off. Pilot project participants will need the benefit of an honest conversation about how the revenues will be utilized. A correctly constructed efficient fee system would clearly indicate where funds should be spent to meet the public's demands. However, there can be a difference between the public's transportation choices in the absence of efficient fees and what they would choose if an efficient fee system made them pay the actual costs they imposed.

An important objective of the pilot project should be to determine how to get the cost of collecting the data as low as possible. The Legislature will need

to be informed of the data being collected, how it will be priced, and how much it will cost. A pilot could take several years to determine these things. Policy makers will want to know if we can reduce the cost of collection so it's comparable to that for the gas tax.

The Legislature has some angst about privacy issues and whether there is an option for a flat fee. Oregon's trucking industry has had transponders in its trucks since the early 1980s. The privacy issue for them was solved by having a private sector firm (EROAD) collect the data. This company has been certified by the Secretary of State and reports the weight-mile tax on behalf of the trucking companies. Another option would be to keep the data inside the device. A person's location would never be sent out, only stored. Unless the need to audit arises before the old data is pushed out by new data, the information would live in the device and never go anywhere else.

There is no technical or institutional implementation that will fully obviate the issue of privacy. There will need to be a combination of an institutional structure people find reasonably trustworthy and a clear articulation of the protections they are entitled to. These include how their data will be managed and how they gain access to their data if they want it.

It was observed that if trust and privacy are such important aspects, the pilot project should test a variety of privacy devices and then query participants as to the level of their trust with each. If the Legislature has concerns about privacy and how it might play out in the full system, it might be less inclined to approve a pilot to begin with. The benefits need to be tied to the concern. In other words, you may give up a little bit of privacy because a private sector company will have your data until you pay your bill, but in exchange you will gain the benefit of an extra 30 minutes a day due to reduced congestion.

Other issues discussed included the fact that there will always be certain parts of the infrastructure that are only lightly used but nevertheless require some maintenance, so the efficient fee system would not apply to these. There would need to be a minimum level of maintenance for the system before variable pricing could take effect. In addition, federal funding levels ten years from now will likely be lower, while the transportation system will need even more help. The state will need to find a way to deal with this reduced federal support.

Also, even in an efficient fee system, there may be roads that need widening due to congestion, but cannot be widened due to land use constraints or existing large-scale structures. There are also a finite number of companies with the ability to perform work on the transportation system, so even with increased revenue the work may not be done in a timely manner. The public needs to see the benefits of efficient fees if the system is going to work.

In summary, the preliminary draft of the paper contains a good theoretical discussion, but needs to be more complete and, in places, concise. Items that need to be retained, added, or discussed more fully include:

- Making the case for an efficient fee system, including discussing the benefits in a way that will resonate with a broad set of readers
- Explaining why a demonstration should be conducted when examples already exist
- Emphasizing the ancillary benefits
- Discussing how some barriers have already been addressed in similar efforts like the Oregon trucking industry's EROAD program
- Including information from ODOT's tolling papers and positioning this pilot program as the next step
- Discussing the benefits to the public versus policy makers
- Discussing the winners and losers, and the constraints that will limit efficiency no matter the fee structure; this is imperative to the paper's integrity

The amount of discussion of other (environmental) externalities and their costs needs to be determined. Mr. Kitchen asked about the top objectives for the paper in order to help him with framing. It was suggested he draft a series of potential objectives for the SRT to rank and then discuss at the next meeting.

The next meeting will be held at 2:00pm on October 20, 2014 at the DAS Executive Building located at 155 Cottage Street NE in Salem, Oregon.

Meeting adjourned: 11:45 am.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF OCTOBER 20, 2014**

2:00 p.m. to 4:00 p.m

DAS Executive Building 155 Cottage Street N.E. Salem, Oregon  
97301-3966.

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation Mazen Malik,  
Legislative Revenue Office  
Mark McMullen, Office of Economic Analysis (Chair) John Merriss,  
Independent Expert (via phone)  
Tim Morgan, AAA Oregon/Idaho  
Don Negri, Willamette University  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Craig Campbell, representing AAA Oregon/Idaho  
Tom Potiowsky, Northwest Economic Research Center  
Jeff Renfro, Northwest Economic Research Center (via phone) Lani  
Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the September 9, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 2:00 p.m. The minutes from the September 9, 2014 meeting received unanimous approval pending a small correction.

### **Presentation on ODOT's Pavement Management System**

Marie Kennedy, a pavement specialist with ODOT's Pavement Management Program, presented the process of collecting Highway Performance Monitoring System (HPMS) pavement data. The Federal Highway Administration (FHWA) has specific requirements for the types of data needed and the proper procedures for collecting that information. Every two years, ODOT hires a contractor whose van has lasers attached to the back bumper. These lasers are able to scan the 12-foot width of highway lanes to determine depth of ruts and the International Roughness Index (IRI). The federal government requires annual reporting of the IRI, so ODOT collects that data itself during years when the contractor is not being used. The survey is conducted on major Oregon non-interstate highways in the far right lane running in the direction of the mile markers, while freeways are examined in both directions, but still only in the right lane.

HPMS data is collected on all the interstates and the National Highway System. IRI measures how much the road causes a vehicle to vibrate and is the most universally accepted type of pavement data. Another criteria, now being phased out, is the Present Serviceability Rating, which is purely subjective and required only if there is not an IRI value to report.

The FHWA requests data be provided in tenths of miles. For rut impressions in the roads, FHWA requests the value reported be the average of the depths in the left and right wheelpaths, measured to the nearest tenth of an inch. ODOT, for its analysis, uses the larger of the two rut depths, measured to the nearest hundredth of an inch. Other data reported to the FHWA includes faulting and percent of cracking, in addition to historical data such as the date of last improvement (of two inches or more thickness), the year of construction, the most recent overlay thickness, the total thickness of the pavement, the type of base material used, and the thickness of the base in inches.

It was asked whether the data collected by ODOT reflects an exponential growth in wear and tear if road repairs are not made in a timely manner. Ms. Kennedy said ODOT's long-term research has shown it is most cost

effective to make repairs when a road is just beginning to show signs of deterioration, and that the Pavement Management System identifies the priorities for rehabilitation and maintenance of pavements.

### **Draft Carbon Tax Research Paper**

Dr. Tom Potiowsky of the Northwest Economic Research Center discussed the carbon tax research paper. Jeff Renfro, the author of the paper, joined the discussion by phone. The purpose of the paper is to determine the implications for highway cost allocation of a carbon tax on the transportation sector. The paper predicts the quantity of fuel used, not miles traveled. Aviation fuel is not included in the analysis, but recreational maritime fuel is included.

The paper examines some of the carbon pricing policies already in existence, including those in British Columbia (B.C.), Ireland, Australia, and South Africa, in addition to small municipalities like Boulder, Colorado. B.C., which is similar to Oregon geographically, has had its program in place since 2008 and it has not appeared to have harmed the economy. B.C. has repatriated its carbon taxes by lowering either corporate or personal income taxes, with some studies showing a very positive net effect. It is too early, however, for comprehensive studies to have been conducted.

As for potential losers, if an industry is heavily dependent on fossil fuels there consequently would be some jobs lost without having a repatriated carbon tax. British Columbia is just beginning an industry-by-industry review of the effects of its carbon tax and decided to exempt some agricultural fuels because they were hearing of negative impacts from the industry. However, in the academic literature statistically significant evidence that the carbon tax has negatively affected the agricultural sector has not been found.

It was asked whether the ripple effects of a carbon tax were analyzed through the entire economy or only in the transportation industry. Mr. Renfro said in the final study the ripple effects through the whole economy will be analyzed, but this paper is just an excerpt of the final study. No other studies were found that examined specific industries or the impact on the transportation sector.

It was asked whether the economic effects of a carbon tax depend heavily on how the tax revenues are repatriated. The answer was yes; however,

the Oregon Constitution requires the revenues from a carbon tax go to the Highway Fund. It was observed that the industries paying the increased tax would suffer if the tax cannot be repatriated back to them, so there would be an impact on the economy as a whole. The Constitution would have to be changed and this needs to be made clear since legislators likely would ask whether the carbon tax can be exempt from the Highway Fund requirements or whether diesel can be exempt from the tax in order to avoid adverse effects on the economy.

The research team felt the carbon tax would work best if it was broad-based with few exemptions. They added it is possible employment in the transportation sector might go up with the additional tax revenues going to the Highway Fund supporting increased road work. In addition, the portion of the carbon tax that could be repatriated could be used to reduce corporate and personal taxes. For sectors that are not heavy energy users, the small amount paid in carbon taxes would be more than offset by the tax break received. Another option would be to target 70% tax neutrality rather than 100%. The remaining 30% would be ear-marked for transportation sectors to assist in fuel switching, road work, public transportation, etc.

It was asked how geographies with carbon taxes in place deal with municipalities. While this study does not drill down to the municipal level, B.C. sets aside a portion of the revenue it receives to support non-profits and government entities. This revenue is used to offset the negative impact of the tax on these entities since the provincial government can't repatriate the tax revenue to these organizations through the tax code.

It was observed that a carbon tax would be regressive for low-income households since a higher percentage of their budget is used for energy. Allowing them to be exempt would create no incentive to switch to other transportation sources. A targeted repatriation system in which higher-income individuals receive less and lower-income individuals receive more may work. Timing is also a critical component for low-income households; having to wait for their annual income tax refund would create a hardship. It was suggested a system similar to Oregon Trail cards with monthly credits might be a solution.

It was noted the term "Transportation Sector" is not defined the same in the beginning as in the second part of the paper, Figure 2 is confusing, and the definition of "Residual Fuel" needs to be clarified. The study team agreed and said all this would be fixed in the final paper.

A carbon tax on fuel would not adequately substitute for the weight-mile tax because it does not increase fast enough with weight, and if a carbon tax were adopted, the weight-mile tax would need to be lowered for lighter trucks and raised for heavier trucks. The diesel tax paid by trucks could be applied through an e-fund mechanism. Diesel should not be exempt from a carbon tax.

To avoid creating a new structure of collection fees, the instruments available now should be used. The carbon tax could be increased using the same methodology currently used for the weight-mile tax. The diesel tax payment made by the trucks currently is refunded through an electronic funds transfer. The carbon tax paid by trucks could also be refunded, but in a way that would add up to the amount paid by all trucks. In this way, truckers would need to detail the number of miles traveled on the weight-mile tax form and then receive a carbon tax refund credit of so many cents per mile. The more efficient trucks would spend less on fees than less efficient trucks at the same weight.

It was agreed there should be more discussion on this at the next meeting. The paper needs to include a discussion of how to comply with both the carbon tax and cost responsibility.

### **Draft of Efficient Fee Research Plan Paper**

Changes to the paper since the last meeting included the addition of a summary as the first section, which Mr. Batten and Mr. Kitchen hope provides a more concise argument for why a demonstration makes sense and how to implement one. In addition, the sections were re-ordered to improve flow, more references to the ODOT papers on tolling were made, and the more technical parts of the document were reduced. Mr. Kitchen still needs to fill in Section 6.6 and all of Section 7.

It was requested additional links and citations be added with regard to the ODOT papers. It was also suggested the portion be augmented concerning building off the Vehicle Mileage Tax (VMT) pilot program that begins in July of 2015. The VMT program will demonstrate the technology and show that much of the work that needs to be done for an efficient fee system is already underway. However, while the VMT work may provide useful information, it was suggested it be kept completely separate from the efficient fee pilot. The technology used in the vehicle and the backend servicing of the VMT data are major pieces of what would be needed for

an efficient fee pilot, but the paper should only reference it and discuss building on that technology rather than adopting or hooking into it.

In addition, it was strongly suggested the paper state when the efficient fee pilot should take place, rather than continuing to leave it unspecified, and clearly explain why it is logical to do it at that time.

It was observed that most new cars today have the technology needed for the pilot, with a GPS system that already talks to the dealership. The program could be phased in by vehicle year, absorbing the vehicles that already have the technology. Two still open questions are when the pilot should begin and how much money it will require.

An SRT member noted by the time the program under Senate Bill 810 (2013) is underway, the efficient fee pilot should be able to piggyback on it and start not too long after the VMT pilot is complete. Another member said it would be fine for the efficient fee program to learn from the VMT pilot, but it would be a mistake to ask the team working on the VMT pilot to alter their plans to take into consideration the efficient fee program.

(At this point in the meeting, the SRT was misinformed that the VMT pilot would be ending in January of 2016. Much of the subsequent discussion was predicated on that misinformation.)

As a whole, the SRT agreed this draft of the efficient fee paper is a vast improvement over the paper from the 2013 HCAS. However, it was noted it will take effort to agree on the objectives an efficient fee would be trying to accomplish and there needs to be a recommendation in the paper of when to begin. The VMT pilot must be given an opportunity to operate and fix any bugs that team might encounter. If the VMT pilot is due to sunset in 2016, the Legislature will have to address that program again or it will terminate. An extension of the VMT pilot might be beneficial if the efficient fee program could build on the information coming out of the extension. The SRT could consider introducing legislation in 2017, recommending the implementation of an efficient fee pilot at a future date that would take advantage of the work being done on the VMT pilot.

The next meeting will be held at 1:00 pm on November 17, 2014 at the ECONorthwest offices located at 222 SW Columbia in Portland, Oregon.

Meeting adjourned: 3:45 pm.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF NOVEMBER 17, 2014**

1:00 p.m. to 3:00 p.m.

ECONorthwest Offices 222 SW Columbia, Suite 1600 Portland, Oregon  
97201

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation Mazen Malik,  
Legislative Revenue Office  
Mark McMullen, Office of Economic Analysis (Chair) John Merriss,  
Independent Expert  
Tim Morgan, AAA Oregon/Idaho  
Don Negri, Willamette University  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Victor Dodier, Oregon Department of Transportation  
Erin Haswell, ECONorthwest  
Lani Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the October 20, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 1:00 p.m. The minutes from the October 20, 2014 meeting received unanimous approval pending a small correction.

### **Draft of Issues Related to VMT and Fuel Tax Revenue Paper**

Vehicle miles of travel (VMT) usually go up and down with the business cycle, but around the year 2000 in Oregon and a couple of years later nationwide, a change occurred which has continued to this day. While the population has continued to grow steadily, per capita VMT has decreased. An increased labor force participation began in the 1960s, but this increase ended around the year 2000. It should be noted that definitions changed with the 2000 census, so for consistency any comparisons made for a paper should begin with that year. After 2000 in Oregon, per capita VMT continued to decline even as the economy was improving up through 2006, and when the economy recently recovered from the recession, per capita VMT was even lower than before. By 2012, it was back down to where it was in 1986.

Possible reasons for the recent decrease in VMT and per capita VMT include: longer distances used to be traveled due to suburbanization and increased non-work-related trips and there was poor transit service; Oregon now has some of the highest transit and bike/pedestrian rates; and millennials (those 15-30 years of age) are choosing to drive less than their parents and grandparents. It was asked how much of the VMT data is from the Portland metro area versus the rest of the state. It would improve the paper to add some regional information.

Trucking activity is driven by business cycles almost exclusively and isn't affected much by fuel prices and other factors. Although other modes of freight transportation have reached capacity, causing truck use to increase, it is only by a small amount and passenger vehicles still represent well over 90% of the vehicles on the road.

Oregon relies on the IHS Inc. (formerly Global Insight) forecast for its outlook, but this forecast is just a residual of the model. Even the Global Insight data is based on the Federal Highway Administration statistics, which are reported by the states and always lag by about two years. The SRT had discussed indexing the fuels tax rate for increased miles per gallon, but the paper indicates it would be too difficult with the data available today.

Dave Kavanaugh, ODOT's revenue forecaster, has a chart showing the expectation for VMT growth to be at a higher rate over the next biennium. It was asked whether this indicates VMT will continue to increase, at least through the forecast period. The answer was yes, if one accepts the forecast. It would be difficult for the group to accept different underlying assumptions about the VMT forecast than what are used for the ODOT budget process. The paper should investigate whether the VMT estimate is predicated on fuel consumption, because then the underlying assumptions may be questionable from the beginning.

It was suggested the paper should offer alternative scenarios, such as how the HCAS results would be impacted if Oregon were to use a different outlook based on demographic factors and alternative assumptions about fuel efficiency. This would avoid the issue of having more than one forecast, but would show how the core HCAS results would likely change if we were to adopt a more permanently pessimistic outlook for VMT. It was also suggested using VMT per job may be a better way of showing the data.

The forecast is aimed at predicting taxed gallons, but the VMT is a function of the assumed weighted average MPG for Oregon and the assumed MPG is a function of the VMT estimates. If the SRT were to use either a higher MPG value or a significantly lower VMT per capita number, how would this affect the equity ratios? Trucks aren't as affected by demographic changes as are cars. Cars would therefore end up with fewer miles of travel, which would reduce their share of those costs allocated on the basis of VMT and shift more of the overall responsibility to the trucks. At the same time, however, this would also change the revenue attribution results, with the share contributed by cars decreasing and the share paid by trucks increasing.

The issue paper needs to include future research needs and note the limitations of the data currently available. A survey of Oregonians about their driving habits and private vehicle usage would provide a better basis for the estimate. Finally, the paper needs to state more clearly the HCAS-related implications of the VMT and VMT per capita trends presented in the paper.

### **Draft of Optional Paper on HCAS Recommendations to the Legislature**

The purpose of this paper is to determine how the SRT can be more certain when making recommendations to the Legislature to change the existing tax rates based on the results of the HCAS. The bottom line study results

are expressed in terms of equity ratios, each defined as the ratio of the share of revenues paid by a particular class of vehicles (e.g., light vehicles or heavy vehicles as a whole) to the share of costs imposed by that class of vehicles.

An equity ratio of 1.00 denotes perfect equity is present, although it's unrealistic to expect this to occur in the real world and every Oregon HCAS since 2001 has found a small inequity in one direction or the other. In past legislative presentations, the study consultants have stressed that measurement and/or forecasting error alone could result in the estimated equity ratios being wrong by as much as 5%. A 5% deviation from perfect equity has therefore been adopted as the informal guideline for whether a recommendation to change the existing tax rates will or will not be made to the Legislature. All recent Oregon HCASs have found equity ratios for light vehicles and heavy vehicles as a whole that are well within this 5% policy guideline.

If future Oregon studies do, for whatever reason, produce equity ratios that deviate by more than 5% from perfect equity (i.e., that are less than 0.95 or greater than 1.05), the paper proposes that if the SRT cannot determine the root cause of the deviation or whether it will continue, then the Legislature should be told that tax rate changes will not be recommended until there is additional information. If two consecutive studies reflect the deviation (in the same direction), the SRT should recommend that the Legislature take action to get the equity ratios back closer to 1.00.

It was noted that a number of factors account for the HCAS not finding significant equity ratio imbalances since 2001: the studies are conducted every two years which doesn't allow much time for change, plus the same consultant has been used each time, as has the same model and essentially the same methodology. There have been only a few major changes in methodology in the last several studies. Among these are the treatment of debt-financed expenditures starting in the 2003 Study and the use of the National Pavement Cost Model (NAPCOM) pavement factors starting with the 1999 Study. Neither of these two changes, however, had a big impact on the overall light/heavy vehicle equity ratio results.

Additionally, Oregon has a user fee system heavily dependent on use of the system, so that the cost allocation results tend to move in tandem with the revenue attribution results. During a recessionary period, for example,

when truck VMT decreases because truck activity is off, fewer revenues will be contributed by the trucks compared to those contributed by cars. At the same time, though, there will be a reduction in the relative responsibility share of the trucks because there are fewer truck miles to allocate on the basis of VMT. Car VMT also fluctuates with the economy, but not by the same percent as does truck travel. The above points should be discussed in the paper, at least to some degree.

It was asked what the downside might be to making the Type One error described in the paper. If the null hypothesis is rejected and the equity ratios are changed when they really don't need to be, what is lost? It is balanced by republishing the rates for the weight-mile tax and the road-use assessment fee, but any change would have both an administrative and political cost.

Although stability is valued, if a big change in the study results is anticipated, perhaps the best approach is to recommend action be taken now since waiting could be more painful to some constituents. However, if the SRT wants the Legislature and interested parties to have confidence in the existing Highway Cost Allocation system, the results should not change radically between studies.

The two items of concern to the trucking industry that could affect the HCAS results are a change in methodology and a change in the project mix. It takes very little change to affect the truck rates. Minor adjustments are usually made to revenue packages to address rate changes and produce equity, which is another reason why the equity ratios found by subsequent studies tend to stay pretty close to 1.00.

As noted previously, the draft paper proposes a 5% deviation from perfect equity as the guideline for recommending tax rate changes to the Legislature, provided this deviation occurs in the same direction for two consecutive studies. There was concern expressed as to whether the 5% applies to the equity ratio for light vehicles or the ratio for heavy vehicles as a whole. Because the weighted average of the two ratios must equal exactly one and because light vehicles account for about two-thirds of the attributed revenues and allocated costs, the equity ratio for light vehicles will always be approximately half as far from one as will the ratio for heavy vehicles.

The above means that if, say, light vehicles are found to be underpaying their responsibility by 5%, then the corresponding overpayment by heavy vehicles could be as high as 10% before a recommendation to adjust the tax rates is made. One member felt an imbalance of this size was simply too large and could trigger legislative action even in the absence of a recommendation for such action by the SRT. It was suggested that triggering a recommendation at a 5% deviation for trucks and 2.5% deviation for cars might be preferable. Others, however, noted that there are a number of different things that when put together could push the results to more than a 5% imbalance. And the possible use of new VMT estimates/forecasts, per the above discussion of the first paper presented at the meeting, could by itself have a significant impact on the study results.

The issue paper needs to focus on the criteria the SRT is going to use to make recommendations to the Legislature or inform them that the results are within the band of equity. It also needs to be made clear that the Legislature is the body which decides when a change in the tax rates needs to be made – the SRT and study consultants recommend, but the Legislature has the ultimate responsibility for deciding “how close (to perfect equity) is close enough”.

If the SRT can determine a useful rule of thumb for the next study to adopt, it would make it easy for the Legislature to understand. The SRT could then make a recommendation based on the numbers without the Legislature having to worry about the technical details.

In writing the paper, Mr. Batten considered a moving average, but that would result in taking a very long time before making any recommendations for change. Instead, the paper proposes taking two studies together before recommending a change in tax rates, since two studies in a row would indicate the results are more than an anomaly and the SRT shouldn't wait to make a recommendation. The SRT wouldn't act off of one study, but use the most recent study for recommending the change. The information presented to the Legislature by the consultant will reflect the recommendations of the SRT.

### **Discussion of Preliminary Study Results**

The study results are still preliminary; however, the one area of concern relates to VMT. When the previous HCAS was completed in 2012, the 2014 total state VMT was predicted to be 38.969 billion. Based on the most recent data provided by Dave Kavanaugh, the revised figure for 2014 is 34.233 billion miles, a decrease of 12%.

The next meeting will be held at 10:00 am on December 19, 2014 at the DAS Executive Building located at 155 Cottage Street NE in Salem, Oregon.

Meeting adjourned: 2:35 pm.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF DECEMBER 19, 2014**

10:00 a.m. to 12:00 p.m.

DAS Executive Building 155 Cottage Street N.E. Salem, Oregon  
97301-3966

Attendees:

### **Study Review Team Members**

Jerri Bohard, Oregon Department of Transportation  
David Hauser, Association of Oregon Counties (for Mike McArthur) Mazen  
Malik, Legislative Revenue Office  
Mark McMullen, Office of Economic Analysis (Chair)  
John Merriss, Independent Expert  
Tim Morgan, AAA Oregon/Idaho (via phone)  
Don Negri, Willamette University  
Bob Russell, Oregon Trucking Associations

### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Michael Bufalino, Oregon Department of Transportation Victor Dodier,  
Oregon Department of Transportation  
Erin Haswell, ECONorthwest  
Lani Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the November 17, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 10:00 a.m. The minutes from the November 17, 2014 meeting received unanimous approval pending a small correction.

### **Presentation of ODOT's Studded Tire Study Results**

Ms. Pennington of the Oregon Department of Transportation (ODOT) presented the newly released study of studded tire use in Oregon. This study provides an update of the previous studded tire study completed in 2000. The purpose of the research is to quantify the current use of studded tires in Oregon and the pavement wear and attendant cost caused by that use. The study-estimated expenditures required to mitigate the pavement wear caused by studded tires are for state highways only and exclusive of any amounts to be spent by local governments on their road systems.

To obtain the information required for the update, the researchers relied on a statewide telephone survey conducted by Portland State University (PSU) during a 29-day period earlier in 2014. 1,944 people completed the survey, a response rate of 23.7%, with a sampling error of +/- 2.2%.

The results of the survey showed a significant drop in studded tire use since its peak in 1994. For ODOT's Region 1 (the Portland area and over to the northern Oregon coast), for example, the studded tire effective usage rate fell from 15.6% in 1995 to 5.1% in 2014. Large declines in studded tire use were exhibited in the other ODOT regions as well. Another significant change between the 1995 and 2014 surveys is in the number of axles on which studded tires are used. The earlier survey showed a mix, with some vehicles using studded tires on both axles and others only on the drive axle, whereas today almost all cars using studded tires use them on both axles.

Other survey findings include the fact that of those who used studded tires last winter season, over 50% started using them more than ten years ago, indicating people who are used to using studded tires have generally continued to do so. Of those people who do not currently use studded tires, 35% said they don't need them, 12% said they don't drive in bad weather, 12% said they have a four-wheel drive vehicle, and 12% have switched to studless winter tires. During the 2013- 2014 winter season, 13% of households used non-studded winter tires, while 11% used studded tires.

The depth of historical data used for this study was not available when the 2000 study was conducted. In addition, ODOT now has access to individual lane traffic data, so they are able to correlate the average daily traffic to the increase in pavement rutting per year. ODOT was able to use a regression analysis to determine a solid rate of wear for the calculations used in the rest of the study.

The methodology used in the 2014 study was as close as possible to that used in the 2000 study, with a few exceptions: (1) The pavement database now has a larger wealth of data, so whenever possible the actual numbers for average daily traffic per section per year for state highways was used. (2) In the 2000 study, the design life for asphalt pavements was taken to be 14 years and for Portland Cement Concrete (PCC) pavements 30 years. In the 2014 study, the design life was updated to 16 years for asphalt pavements and 40 years for PCC pavements. (3) The 2000 study used three rates of wear with nine total scenarios, while the 2014 study used one rate of wear with three total scenarios based on short, medium and long design lives.

It was asked what the difference in the size of the survey was between 1995 and 2014. Ms. Pennington indicated she would research the question. (The 1995 survey contacted 3,107 households owning a total of 6,329 vehicles). The 1995 survey was done by the University of Oregon, while the 2014 survey was conducted by PSU.

Unlike the study in 2000, a parking lot survey was not conducted this time. It was observed that with such a survey, only the subset of cars that are “out and about” at a particular time are considered. In addition, without the use of a telephone survey to inquire how much drivers use cars with studded tires, it would be difficult to estimate how many miles to attribute to vehicles with studded tires versus those without such tires.

The telephone survey also asked how participants are able to travel during inclement weather, as well as how many miles are driven on a typical day and, if they used studded tires, the months those tires were put on and removed. This provided valuable information that simply could not be obtained via a parking lot survey, making the telephone survey a superior instrument for use in the 2014 study. The full survey is reproduced in the appendix of the study report, along with all the participants’ comments.

Ms. Pennington was asked about the decline in the percent of total traffic accounted for by passenger vehicles in ODOT Regions 3, 4 and 5 (basically southwestern, central and eastern Oregon, respectively). This could relate to the change in methodology and getting the count data by lane. She indicated she would ask the pavement experts. (The methodology for classifying passenger vehicles has not significantly changed since the 2000 study.) The data for the current report is deeper because the average daily traffic per lane was examined to get the vehicle type percentage factors. Generally that information is collected and aggregated so the detail is lost, but because the traffic planning division knew about this study they looked at it more closely and derived these percentages for the lane splits.

The 1995 survey used repair costs of \$52,800 per lane-mile, whereas the cost in 2014 was \$98,300 per lane-mile. The assumptions between the two studies were the same, except that in the 2014 survey the lane distribution data was included along with the updated design life assumptions for both asphalt and PCC pavements. Oregon does occasionally patch just the pavement ruts and not the entire lane or road. The assumption is that a rut requires repair when it becomes 0.75 inches deep, the same assumption as used in 1995.

It was asked what the figure of \$27.2 million in total damage for 2012 represents. This figure was derived by three completely different methodologies. It looked at the vehicle miles traveled (VMT) by region in 2012, and factored in studded tire use and the proportion of total travel accounted for by passenger vehicles.

Those numbers resulted in the VMT of studded tires, which was then multiplied by the studded tire wear rates for asphalt and PCC pavements. The \$27.2 million in total damage represents the full cost of fixing all the pavement damage caused by studded tires in 2012. The 2012 effective damage figure of \$8.54 million represents only the additional cost over the regularly scheduled pavement overlays.

It was asked why the cost to repair PCC pavements fell so drastically from 1995 to 2012, from \$5.3 million to \$0.9 million. The majority of PCC pavements are in Region 1, where the effective studded tire usage rate decreased from 15.6% in 1995 to 5.1% in 2014. The damage in Region 1 decreased significantly, but the rate of wear on PCC pavements is also

very low (about 0.0091 inches per 100,000 studded tire passes versus 0.0295 inches per 100,000 studded tire passes for asphalt pavements) and the amount of wear did not change significantly from the 2000 study. In addition, the 2000 study was looking at wear rates based on the older, heavy (steel) studs. Add to that the assumed change in design life for PCC pavements from 30 to 40 years and that the figure is based on roads requiring regular repairs more frequently than studded tire damage alone could cause, and the result is far less studded tire damage on PCC highways in Region 1.

It was asked whether the new lightweight studs cause less damage on PCC pavements than on asphalt pavements. That is beyond the scope of this analysis, but repair costs for the two pavement types are not the same. Asphalt pavements can have only the rut repaired, whereas PCC roads require all lanes plus the shoulders to be repaved. It was asked if the \$98,300 per lane-mile repair cost is being assumed for both pavement types. The cost estimate is a weighted average that takes into account the relative number of lane miles of each pavement type. It was suggested Region 1 be contacted to try to correlate the actual expenditures made on PCC roads due to studded tire damage with the estimate in this study.

It was noted that Region 3 shows zero impact from studded tires, both in 1995 and 2012. Because the winter weather in Region 3 is relatively mild, the conclusion is the minimal damage caused by studded tires in this region doesn't ever impact the regular overlay schedule dictated by design life.

It was suggested an effort be made to increase public awareness of the effectiveness of studless tires, since studded tires provide only an incremental increase in traction but cause a more dramatic increase in road damage and repair costs.

### **Model Results and Draft Study Report**

There were a number of minor changes from the preliminary model results, but not many changes from the last Highway Cost Allocation Study. The equity ratios for light vehicles and heavy vehicles as a whole are very close to 1.0000 in both studies, signifying almost perfect equity in the existing tax rates and user fee levels.

The VMT is different from that used in the previous study, but because the pattern is similar Mr. Batten does not believe there are any errors in the model routine that produces the weight-mile tax VMT. Dave Kavanaugh's total VMT numbers were used, which included an assumed 2.1% average annual growth in light vehicle travel and 3.03% average annual growth in truck miles of travel.

A bigger question is whether the recently observed reduction in per capita VMT will continue or stop. Although VMT generally isn't all that sensitive to gas prices, if gas prices were to decline and stay down for an extended period of time there could be a noticeable response. The problem is that actual passenger car VMT is unknown and therefore has to be estimated. It was suggested the study use a range of VMT outlooks to show how each would impact the equity ratios. The issue paper on the future of VMT could show how changes in the assumed future growth of VMT affect the highway cost allocation results.

### **Discussion of Presentation to Legislative Committees**

There will be probably two or three HCAS presentations at different times in late February or early March. It was recommended there be two presentations: one each for the House and the Senate, with the Revenue and Transportation Committee members invited to attend. It was suggested the Efficient Fee issue paper be included in the presentation.

The HCAS results are essentially that nothing's changed since the last study, but the Legislature will want to know whether they are constitutionally required to enact any legislation. The presenters could explain the report with enough detail to make legislators comfortable with the recommendation that no action on their part is required. With regard to an efficient fee, the SRT can say that according to the traditional study, the results are fair between trucks and cars, but there are inequities within the broad groups. The presenters can then discuss the efficient fee concept and long-term viability of Oregon's road user tax structure, while also advising the legislators to wait until 2017 before considering an efficient fee in order to get beyond implementation of the VMT fee.

At the next HCAS meeting, the SRT will discuss in more detail what will be presented to the Legislature and by whom. Mr. McMullen described dividing the presentation into three parts: a technical presentation by Mr.

Batten and Mr. McMullen, a philosophical discussion of the long-term viability of our current system by Dr. Negri and other stakeholders, and recommendations to the Legislature by Mr. Malik and other stakeholders on what it needs to do either during this legislative session or by 2017. The SRT needs to be prepared to address how the state will index for increased fuel efficiency. The Transportation Forum has promising proposals in that area.

The next meeting will be held at 1:00 p.m. on January 26, 2015 at the DAS Executive Building located at 155 Cottage Street NE in Salem, Oregon.

Meeting adjourned: 11:35 am.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF JANUARY 26, 2015**

1:00 p.m. to 3:00 p.m.

DAS Executive Building 155 Cottage Street N.E. Salem, Oregon  
97301-3966

### **Attendees:**

#### **STUDY REVIEW TEAM MEMBERS**

Jerri Bohard, Oregon Department of Transportation  
David Hauser, Association of Oregon Counties (for Mike McArthur) Mazon  
Malik, Legislative Revenue Office  
Mark McMullen, Office of Economic Analysis (Chair)  
John Merriss, Independent Expert  
Tim Morgan, AAA Oregon/Idaho  
Don Negri, Willamette University  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Association

#### **SUPPORT STAFF AND FRIENDS OF THE SRT**

Carl Batten, ECONorthwest  
Patrick Brennan, Administrator, House Transportation Committee Michael  
Bufalino, Oregon Department of Transportation  
Craig Campbell, representing AAA Oregon/Idaho  
Victor Dodier, Oregon Department of Transportation  
Heidi Elliott, Legislative Counsel  
James LaBar, Administrator, Senate Business & Transportation Committee  
Julie Neburka, Legislative Fiscal Office  
Lani Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the December 19, 2014 HCAS Review Team Meeting Minutes**

The meeting began at 1:00 p.m. The minutes of the December 19, 2014 meeting received unanimous approval.

Mr. McMullen reminded the Study Review Team (SRT) that he is required to send a letter to the Legislature by Friday, January 30, 2015 stating that the 2015 Highway Cost Allocation Study (HCAS) has been completed, the SRT has endorsed the results, and the study is ready to be presented to the appropriate legislative committees at their convenience.

### **Discussion and Approval of the 2015 HCAS Final Report**

The major results of the HCAS are traditionally expressed in terms of equity ratios, defined as the ratio of the share of total revenues paid by the vehicles in each class to the share of total costs (expenditures) for which the vehicles in that same class are responsible. The results of the 2015 Study are applicable for the upcoming, 2015-17 biennium and, following the approach of past Oregon studies, the equity ratios are calculated for full-fee-paying vehicles only.

Mr. Batten reported the calculated equity ratios for this study are 0.9993 for light (up to 10,000 pound) vehicles and 1.0013 for all heavy (over 10,000 pound) vehicles as a group. This means that for the next biennium and under the existing highway user tax and fee rates, full-fee-paying light vehicles are projected to underpay their responsibility by 0.07% and full-fee-paying heavy vehicles, as a group, to overpay their responsibility by 0.13%. The very small deviations from one in these equity ratios signify a situation of near perfect equity.

The above means the user fee rate schedules in effect currently are likely to work well in the upcoming biennium as long as the way the money is budgeted to be spent isn't changed. However, if there is a transportation funding package or other legislation that would necessitate a change in the tax and fee rates, Mr. Malik will be able to use the study results to design rates that keep things in balance.

The report shows light vehicles are projected to pay 64.6% of the full fee revenues and impose 64.7% of the full fee costs. Heavy vehicles, as a group, are expected to pay 35.4% of the revenues from full-fee-paying vehicles and impose 35.3% of the full fee costs. For both groups of vehicles, dividing the payment share percent by the cost responsibility

share percent (with all four percent figures carried out to additional decimal places) gives rise to the aforementioned equity ratios of 0.9993 for full-fee-paying light vehicles and 1.0013 for full-fee-paying heavy vehicles as a group.

It was asked why the equity ratio for the 78,001 to 80,000 pound class is so high and seems to keep increasing from one study to the next. Mr. Batten said it's because so many heavy, five-axle trucks choose to declare at 80,000 pounds, even though a portion of their miles are operated at significantly less than 80,000 pounds. This is an artifact of their being common carriers and moving whatever loads need to be moved. Because damage to pavements increases rapidly with increases in vehicle axle weights and because the study allocates pavement costs on the basis of actual operating weights, the vehicles in this class actually do less damage than those in other classes where average operating weights are closer to declared weights. This results in vehicles in the 78,001 to 80,000 pound class paying significantly more than their fair share.

The single weight class of 78,001 to 80,000 pounds accounts for more than twice as many miles as all the classes between 26,001 and 78,000 pounds. This is partly due to the fact that 80,000 pounds is the maximum federal legal limit. Trucks declared at 80,000 pounds can move throughout the country without impediments, making it the most common weight. A trucker operating in Oregon declares his or her vehicle at the highest weight it will be operated at during the reporting period and pays the weight-mile tax for that weight no matter the actual operating weight.

It was asked whether the report should explain that it would be almost impossible to achieve an equity ratio of exactly one and would be pure happenstance if it did occur. While the SRT cannot make recommendations to the Legislature, it can mention previous practice. The studded tire study results and the current mix of road projects both contributed to the near perfect equity ratios for light vehicles and heavy vehicles as a whole. It was agreed the picture on the front of the report should be changed. The SRT was asked to finish its review of the computations in the Final Report by the end of the week in order to guide Mr. McMullen in his letter to the Legislature. Any non-substantive suggested changes to the document are to be forwarded to Mr. Batten for his consideration.

### **Discussion of Presentation to Legislative Committees**

The SRT, specifically the Chair, has a statutory responsibility to present the HCAS to the Legislature, although most of the actual presentation has traditionally been delegated to the study consultants. The presentation should include a history of the study and why it's done, as well as an explanation of why the numbers in the current study did not change all that much from the last study. The SRT considered discussing the potential results of reforming the system, given that the current funding mechanism is not sustainable over the long term. The SRT could then discuss the implications for the HCAS, including pilot studies and white papers concerning long term trends, the increasing fuel efficiency of the fleet, and equity within the light vehicle classes.

Explaining an efficient fee system is complicated, but essentially we would be determining both where road damage is occurring and how to efficiently spread out its cost. When people drive, in addition to road damage they create congestion and pollution. To be truly fair, some of the reforms the SRT is considering would need to take into account these broader costs. The SRT needs to decide either to minimize its work on the efficient fee issues or provide time for the Department of Transportation to talk about Oregon-specific issues and why some of the theory may or may not be suited to Oregon.

It was suggested the SRT provide the issue papers to the Legislature and allow them to say if they would like the SRT to return to discuss them further. The presentation should mention that we don't want anything to happen until the 2017 session, although this depends on whether there is going to be a transportation funding package this session. The SRT could provide an introduction and context on how cost responsibility and the HCAS results need to be incorporated in the development of any transportation package.

It was suggested the SRT present to the transportation committees and then talk to the Chairs to see if they would like to have a discussion of the efficient fee paper. Mr. Brennan suggested the presentation be during the Transportation Committee's regular meeting time; then during the interim the members could ask for a deeper discussion.

Mr. McMullen asked the group to review the report and the issue papers that are ready. Mr. Batten asked the Department of Transportation representatives to review the efficient fee paper and indicate areas that would be implementation challenges. If the primary concerns are from ODOT, then Ms. Bohard and Mr. Batten can work outside the group and report back to the full SRT. Ms. Bohard asked for a list of the papers, indicating how complete each is, an estimate for when each will be final, and which version needs to be reviewed.

In the event the SRT needs to meet again to review the issue papers and plan its testimony, one additional meeting has been tentatively scheduled for Friday, February 20, 2015. This meeting would take place at the DAS Executive Building located at 155 Cottage Street NE in Salem, Oregon.

Meeting adjourned: 2:16 p.m.

## **OREGON HIGHWAY COST ALLOCATION STUDY REVIEW TEAM MEETING MINUTES OF FEBRUARY 20, 2015**

2:00 p.m. to 4:00 p.m.  
DAS Executive Building  
155 Cottage Street N.E.  
Salem, Oregon 97301-3966

### **Attendees:**

#### **STUDY REVIEW TEAM MEMBERS**

Jerri Bohard, Oregon Department of Transportation (via phone)  
David Hauser, Association of Oregon Counties (for Mike McArthur)  
Mazen Malik, Legislative Revenue Office  
Mark McMullen, Office of Economic Analysis (Chair)  
John Merriss, Independent Expert (via phone)  
Tim Morgan, AAA Oregon/Idaho (via phone)  
Don Negri, Willamette University  
Doug Parrow, Independent Expert  
Bob Russell, Oregon Trucking Association

#### **Support Staff and Friends of the SRT**

Carl Batten, ECONorthwest  
Craig Campbell, representing AAA Oregon/Idaho  
Victor Dodier, Oregon Department of Transportation  
Erin Haswell, ECONorthwest  
Lani Pennington, Oregon Department of Transportation  
Amy Williams, Oregon Department of Administrative Services

### **Approval of the January 26, 2015 HCAS Review Team Meeting Minutes**

The meeting began at 2:00 p.m. The minutes of the January 26, 2015 meeting received unanimous approval.

### **Discussion of Final Draft of Efficient Fee Paper**

Pursuant to distribution of the efficient fee issue paper, Matthew Kitchen sent a memo to the Study Review Team (SRT) and addressed many of the concerns Ms. Bohard had previously raised. Ms. Bohard said she would like the paper to acknowledge there are existing unknown factors, and these will need to be determined both by working with stakeholders and by analyzing the results of the Vehicle Miles Traveled (VMT) pilot project currently underway. Additionally, Ms. Bohard would like to have Section 6.1.3. of the issue paper incorporate the information in Mr. Kitchen's memo and acknowledge the complexity of the issue.

### **Discussion of Final Model Results**

Shortly after the previous SRT meeting, an error was discovered in the model's calculation of the VMT by federal vehicles. Correcting this error changed several of the VMT amounts and this in turn resulted in small revisions to the major equity ratio results previously reported at the January meeting.

The new, revised equity ratios are 1.0015 for full-fee-paying light (up to 10,000 pound) vehicles and 0.9973 for all full-fee-paying heavy (over 10,000 pound) vehicles as a group. This means that for the 2015-17 biennium and under the existing highway user tax and fee rates, full-fee-paying light vehicles are projected to overpay their responsibility by 0.15% and full-fee-paying heavy vehicles, as a group, to underpay their responsibility by 0.27%. This represents a reversal of the previously reported results which had projected a slight underpayment by light vehicles and a slight overpayment by heavy vehicles. However, as was the case with the earlier equity ratios, the revised ratios are very close to one, signifying a situation of close to perfect equity.

Ms. Pennington will continue to review the model and the members were urged to carefully check the revised results to make sure there are no remaining problems with the numbers. The study Final Report will need to be posted on the web site for the Office of Economic Analysis for public consumption. There was concern expressed over any errors in the model if

Mr. Malik needs to calculate tax rates for a transportation funding package. It was suggested a spreadsheet be provided showing the difference between past and current results to highlight the differences more easily. Mr. Batten said he could compile that information back to 2005. The goal will be to have that circulated within a few days and final testing of the model and revised results completed within the next week.

### **Discussion of Presentation to the Legislature**

The presentations to the House and Senate revenue and transportation committees are tentatively scheduled for mid-March. The SRT discussed whether to speak about an efficient fee system and pilot project. The consensus was to introduce the topic now, with the knowledge that implementation would be at least several years away. The conversation could focus on the future of transportation financing with a discussion of an efficient fee system, the Department of Transportation providing an update on the VMT pilot project, and the stakeholders outlining why the current system is not sustainable and the path that lies ahead.

The discussion of the issue papers and HCAS results should be brief (only about two slides each) in order to present a high level overview and allow the committee members to ask questions if they are interested. The SRT should also show a willingness to return if the committee members would like more information.

Mr. McMullen will circulate the proposed legislative presentation to the SRT, as well as the information on comparative equity ratios over time from Mr. Batten. In addition, the VMT, carbon tax and efficient fee issue papers still need to be finalized. The final model results will need to be approved by the SRT either by conference call or email. Mr. McMullen is hoping to post the final study results and issue papers as soon as possible.

Meeting adjourned: 2:35 p.m.

# Appendix D: Model User Guide

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## I. INTRODUCTION

The 2015 Oregon Highway Cost Allocation Study (HCAS) Model User Guide describes the steps required to update and run the 2015 version of the Oregon HCAS Model. A user should be able to modify the model assumptions and update the input data and then rerun the model with the information in this user guide, along with instructions in the model tabs.

[Section 2, Model Overview and Summary](#), provides a general overview of the HCAS model and describes the input data structure.

[Section 3, System and Software Requirements](#), describes the computer system requirements and software required to run the model.

[Section 4, Initial Model Setup](#), describes the model distribution and its folder and file setup.

[Section 5, Install Python and Openpyxl](#), describes how to install Python 2.7 and Openpyxl on a Windows operating system.

[Section 6, Set Up a New Scenario](#), describes how to set up a new scenario to run the Python HCAS model on (e.g., if the user wants to use different inputs and/or assumptions).

[Section 7, Run the HCAS Python Model](#) describes how to run the HCAS Python model using a Graphic User Interface (GUI) for Python.

[Section 8, Input Data and Data Preparation](#), describes the data and any data pre-processing required to update the HCAS model.

[Section 9, Input Text Files](#), describes the input text files. Each input file is described in terms of the file contents and the data required to update the input text file.

[Section 10, Inputs Workbook](#), describes the inputs workbook. The tab-by-tab explanation of the model displays a screen shot of the model tab, and then describes the contents of the tab, how the data on the tab are used in the model, and the process for updating the data and other user-specified assumptions.

[Section 11, Output Files](#), guides the user through the outputs workbook and output text files.

[Section 12, Policy Analysis of Alternative Rates](#), is a user guide for an alternative rate analysis using the HCAS model. This section describes the various revenue instruments of the model, along with how alternative rates for each instrument will affect the HCAS model results. The *Alt. Rates* input tab and *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary* output tabs are explained in a tab-by-tab fashion. This section also has case studies that provide step-by-step examples of how to conduct an alternative rates analysis for different revenue instruments.

## 2. MODEL OVERVIEW AND SUMMARY

The purpose of the HCAS is to determine whether each class of highway users is paying its fair share. Paying one's fair share is defined as contributing the same share of total revenues as the share of costs that one imposes.

The HCAS model calculates each user class's share of costs and then the user class's share of revenues to calculate equity ratios for each user class. Equity ratios close to one indicate that

the user class is paying its fair share of costs. An equity ratio less than one indicates the user class is paying less than its share of costs, and an equity ratio greater than one indicates the user class is paying more than its share of costs.

The 2015 Oregon HCAS model is written in Python and requires data inputs in the form of an input Excel workbook and input text files. The input workbook is the user interface for updating data and assumptions used in the model calculations. An output workbook and text files are the result of running the HCAS model.

The 2015 Oregon HCAS model differs from the model structure used in the 2013 HCAS in terms of how the HCAS Python model is actually run and how the folders and files are structured. However, the core of the HCAS Python model and the required inputs and outputs remain unchanged. In the 2013 HCAS, there was one Excel workbook that had both input and output workbook tabs and had Visual Basic Application (VBA) code that called the HCAS Python model code.

In the 2015 HCAS, the user now runs the HCAS Python model through a Python Graphic User Interface (GUI) (steps to run a Python file are discussed in-depth in [Section 7, Run the HCAS Python Model](#)). This allows the model to be more interchangeable between operating systems and improves reliability of outputs. Another change is that instead of one large workbook with input and output tabs, there are two separate workbooks; one for the inputs ("*HCAS Inputs 2015.xlsx*", oftentimes referred to as the "inputs workbook") and one for the outputs ("*HCAS Outputs 2015.xlsx*", oftentimes

referred to as the “outputs workbook”). The change from one workbook to two workbooks provides more clarity on the model input-output process.

Model assumptions and many data inputs are located in the inputs workbook. The workbook is described in detail in [Section 10, Inputs Workbook](#). The rest of the input data are in the input text files. These files are described in detail in [Section 9, Input Text Files](#).

The tabs in the inputs workbook are oriented from left to right, with the main control and assumption tab (*General*) at the far left, followed by the tabs for VMT inputs, cost inputs, revenue inputs, and other inputs (e.g., *MPG*, *Policy*).

To update and run the model, the user edits the model input data, parameters and assumptions as needed, saves the inputs workbook and then runs the Python HCAS model code. Instructions to run the Python HCAS model code are provided in [Section 7, Run the HCAS Python Model](#).

Running the HCAS Python model code will read in the data from the inputs workbook and the input text files. Using these data, the HCAS model will perform the VMT analysis, cost allocation, revenue attribution, and alternative rates revenue attribution calculations. The HCAS model will then generate a set of output text files in an outputs folder and populate an outputs Excel workbook with the HCAS model results. [Section 11, Output Files](#), describes these output files. The structure of the Python code and model calculations are provided in Appendix E.

### 3. SYSTEM AND SOFTWARE REQUIREMENTS

This section describes the computer system and software requirements to update and run the HCAS model.

As noted in [Section 2, Model Overview and Summary](#), the 2015 Oregon HCAS model is a model written in Python that requires data inputs in the form of an input Excel workbook and input text files. The model also requires these input files along with an output template Excel workbook to be in a particular folder setup. This section discusses the system and software requirements for the model. The following section discusses the distribution format of the model and the folder and file setup for the model.

#### SYSTEM AND SOFTWARE REQUIREMENTS

The HCAS model can be updated and run using standard computer software and available open-source programming software. The user must install the requirements listed below prior to implementing the HCAS model.

##### System Requirements

The HCAS model works on Windows and Macintosh Operating Systems. The steps outlined in [Section 5, Install Python and Openpyxl](#), provide screenshots of the process to install Python on a computer running Windows 7. The process may look different if the user is running a different version of Windows.

##### Excel

The HCAS model requires Excel input and output workbooks using a version of Microsoft Office Excel 2007 or later. The file extension format of all Excel workbooks is “.xlsx.”

##### Python

Python is an open-source, object-oriented programming language. The user must download and install the Python software maintained by the Python Software Foundation.<sup>1</sup> The user must also install the Python package Openpyxl that is used to read and write Excel workbooks.<sup>2</sup> (See [Section 5, Install Python and Openpyxl](#).)

##### Text Editor

A text editor or Excel can be used to view input and output tab-delimited text files.

##### Database Software

Pre-processing of some of the original data files must be done outside of the HCAS model due to the size of the data sets or the type of data tabulations. The pre-processing can be done using desktop database software such as PostgreSQL or Microsoft Access. PostgreSQL is an open-source object-relational database management system (DBMS) that supports the SQL programming language.

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<sup>1</sup>Python can be downloaded from: <http://www.python.org/download>. The Python Software Foundation website also contains documentation and other related material. Instructions on how to install Python 2.7 are provided in [Section 5, Install Python and Openpyxl](#). The user should consult the Python documentation for additional information on how to install the program and open the Python editor.

<sup>2</sup>Openpyxl can be downloaded using Pip, a Python package installer or can be downloaded directly from <https://pypi.python.org/pypi/openpyxl>. Pip is automatically installed in the default installation of Python 2.7.9 from the Python Software Foundation. More detailed instructions on how to install Openpyxl are provided in [Section 5, Install Python and Openpyxl](#), and the model distribution's README.rtf.

## 4. INITIAL MODEL SETUP

### MODEL DISTRIBUTION

The 2015 HCAS model is available to download in a ZIP archive file format (“2015 Oregon HCAS Model.zip”). Unzipping this file will automatically set up the correct folder structure and includes all of the 2015 HCAS input files that are required to run the model.

### INITIAL FOLDER AND FILE SETUP

First, the user must unzip the model distribution file, “2015 Oregon HCAS Model.zip.” This can usually be done by double clicking on the file. Doing this will create a new folder, “2015 Oregon HCAS Model.” [Figure 1](#) shows the original ZIP file and the result of unzipping the ZIP file.

[Figure 2](#) shows the first level folders of the “2015 Oregon HCAS Model” folder (this may be referred to as the “base model folder”). The base model folder has four first level folders: *code*, *processed scenarios*, *scenarios*, and *template\_outputs*. There is also a README.rtf text file that has general instructions on how to run the model on a Windows Operating System. [Figure 3](#) shows the contents of these four folders.

#### code

The *code* folder has two files: python-2.7.9.msi and HCASModule.py. The user should not make any modifications to files in the *code* folder.

“python-2.7.9.msi” is a Python distribution file downloaded from the Python Software Foundation that has the required version of

Python to run the HCAS model. The user may use this file to install Python 2.7 (see [Section 5, Install Python and Openpyxl](#)).

“HCASModule.py” is a Python file that contains the HCAS model code and is what the user will open to run the HCAS model. Executing this file will run the HCAS model code that performs the model calculations (e.g., VMT analysis, cost allocation and revenue attribution). [Section 7, Run the HCAS Python Model](#), describes how to open this file and run the HCAS model in Python.

#### scenarios

The *scenarios* folder is a place to put scenarios that the user is actively working on (i.e., scenarios the user wants to run through the HCAS model). Each scenario will have its own folder in the *scenarios* folder (this folder can be named whatever the desired scenario name is).

One template scenario is provided in the standard model distribution in the folder entitled “Example Scenario.” The contents of this folder are illustrated in [Figure 4](#). As illustrated in the *Example Scenario*, the scenario folder must have an *inputs* folder. The *inputs* folder must have an Excel inputs workbook and a folder entitled *txt\_2015*. All of the input text files should be placed in the *txt\_2015* folder.

[Figure 4](#) shows the required structure for the *inputs* folder along with the required filenames. The Excel inputs workbook should be entitled “HCAS Inputs 2015.xlsx” and the input text files must have specific names (see names listed in the *txt\_2015* folder in [Figure 4](#)).

**Figure 1. Model Distribution Files**

Name	Kind
2015 Oregon HCAS Model.zip	ZIP archive
2015 Oregon HCAS Model	Folder

**Figure 2. Model Base Folders**

Name	Kind
2015 Oregon HCAS Model	Folder
code	Folder
processed scenarios	Folder
scenarios	Folder
template_outputs	Folder
README.rtf	Rich Text Document

**Figure 3. Model Base Folder Contents**

Name	Kind
2015 Oregon HCAS Model	Folder
code	Folder
python-2.7.9.msi	Document
HCASModule.py	Python Source
processed scenarios	Folder
scenarios	Folder
Example Scenario	Folder
template_outputs	Folder
HCAS Outputs 2015.xlsx	Microsoft Excel workbook
README.rtf	Rich Text Document

**Figure 4. Scenario Input Files**

Name	Kind
Example Scenario	Folder
inputs	Folder
HCAS Inputs 2015.xlsx	Microsoft Excel workbook
txt_2015	Folder
AxleShares.txt	Plain Text Document
BasicSharePeak.txt	Plain Text Document
Bonds2003-2005.txt	Plain Text Document
Bonds2005-2007.txt	Plain Text Document
Bonds2007-2009.txt	Plain Text Document
Bonds2009-2011.txt	Plain Text Document
Bonds2011-2013.txt	Plain Text Document
Bonds2013-2015.txt	Plain Text Document
DeclaredOperating.txt	Plain Text Document
DeclaredRegistered.txt	Plain Text Document
PaveFactors.txt	Plain Text Document
PCEFactors.txt	Plain Text Document
SeedData.txt	Plain Text Document
SimpleFactors.txt	Plain Text Document

The *Example Scenario* folder and its *inputs* folder simply serve as a template scenario that the user may use as a starting point to create the scenario the user wants to run. The primary HCAS model user interface to change assumptions and input data is the Excel inputs workbook, “HCAS Inputs 2015.xlsx”. (See [Section 6, Set Up a New Scenario](#) for more information).

**processed scenarios**

Once the user runs a scenario through the HCAS Python model and is satisfied with the model results, the user should move the scenario’s folder from the *scenarios* folder to the *processed scenarios* folder. The user may click on the folder and drag it from the *scenarios* folder to the *processed scenarios* folder.

Alternatively, the user may open the *scenarios* folder, right click on the particular scenario’s folder and select “Cut.” The user should then open the *processed scenarios* folder, right click and select “Paste.” (See [Section 6, Set Up a New Scenario](#) for more information).

**template\_outputs**

The *template\_outputs* folder has one file, an Excel workbook “HCAS Outputs 2015.xlsx.” This workbook serves as a template workbook with some basic text and header formatting, but does not have HCAS model output data. The user should not make any modifications to template Excel workbook in the *template\_outputs* folder.

When the user runs the HCAS Python model for a scenario, this template workbook, “HCAS Outputs 2015.xlsx”, is copied into the scenario’s *outputs* folder and is filled with the results of the HCAS model for that scenario.

The scenario’s name is added to the filename. For example, if the scenario’s folder name is “Final Final”, a result of running the model is the creation of a new workbook in the *outputs* folder entitled, “HCAS Outputs 2015 Final Final.xlsx.” Similarly, if the scenario’s folder name is “Scenario 1”, the result of running the model is the creation of a new workbook entitled “HCAS Outputs 2015 Scenario 1.xlsx.”

## 5. INSTALL PYTHON AND OPENPYXL

The user should complete the steps outlined in this section to install Python 2.7 and Openpyxl on the user’s operating system.

These instructions are for a Windows 7 operating system. The general steps should be the same for other Windows operating systems, but some things may differ. For example, the way to search for a program or the way the window screen looks may differ from the directions provided in this user guide.

### I. INSTALL PYTHON 2.7

This sub-section describes the steps to install Python 2.7. If the user already has Python 2.7 installed, the user may try to skip to the following sub-section, [2. Install Openpyxl](#).

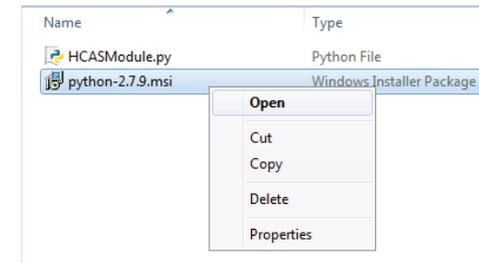
If the user runs into issues later on when trying to install Openpyxl or running the HCAS Python

model, reinstalling a new, clean version of Python 2.7 by following these steps may resolve those issues.

**Steps:**

- Step 1.1: Open the *code* folder (a first-level folder of the “2015 Oregon HCAS Model” folder, see [Figure 2](#)). In the *code* folder, right click on “python-2.7.9.msi” and select “open” from the right click options (see [Figure 5](#)).

**Figure 5. Step 1.1: Open python-2.7.9.msi**



**Figure 6. Step 1.2: User Install Options**

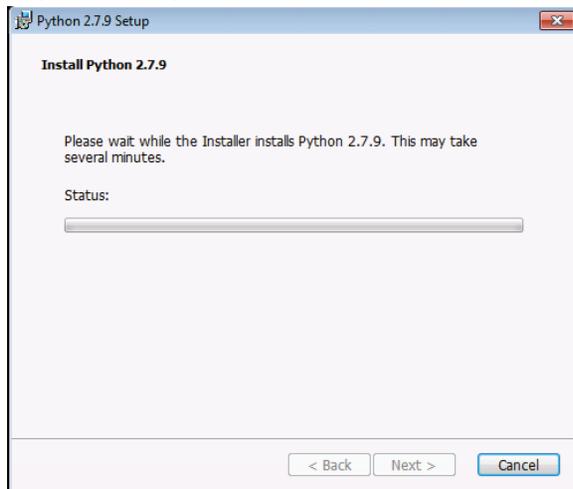


- Step 1.2: A Python 2.7.9 Setup window (like the one displayed in Figure 6, on the previous page) should open up. In the Python 2.7.9 Setup window, select the option “Install for just me (not available on Windows Vista).” Click “Next.”

**Figure 7. Step 1.3: Directory Install Options**

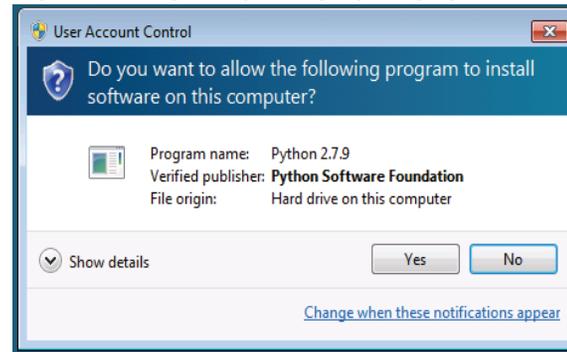


**Figure 8. Step 1.4: Start Installation**

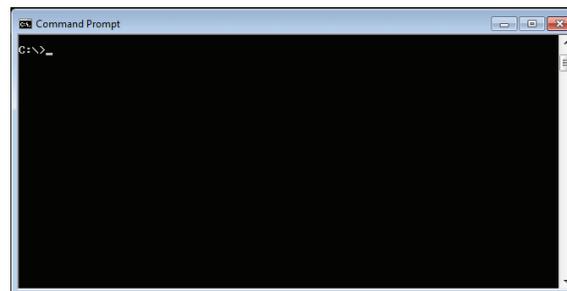


- Step 1.3: The next window sets up the installation directory for Python 2.7 (see Figure 7). The installer should automatically select the correct folder to install Python 2.7 in. The default installation location is “C:\Python\27”. If the text in the bottom-most white text box does not say “C:\Python\27”, modify the text in the box so that it says “C:\Python\27”. Click “Next.”
- Step 1.4: The next window will start the installation of Python 2.7 (see Figure 8). Wait until the installation finishes. This may take a couple minutes, and there may be some additional windows that pop up during the process. If a window pops up asking

**Figure 9. Step 1.4 (Example): Popup Window**



**Figure 10. Step 1.4 (Example): Popup Window**



whether the user wishes to continue with the installation, the user should click “Yes” to continue. An example of what this type of window might look like is illustrated in Figure 9. Another window that looks similar to the window illustrated in Figure 10 (on the following page) may also pop up - this window will open and close automatically, the user should not try to close this window.

- Step 1.5: The installation has finished when the “Finish” button option becomes an available option to click on (see Figure 11). Click “Finish.”

**Figure 11. Step 1.5: Finish Installation**



## 2. INSTALL OPENPYXL

The following steps walk the user through installing Openpyxl. Openpyxl is a Python package that reads and writes Excel files. It is easiest to install through Pip, a Python package manager that is automatically installed when the user installs Python 2.7 using the default installation options. The steps provided in the previous sub-section, [1. Install Python 2.7](#), install the default version of Python 2.7.

It is recommended to try to install Openpyxl using Pip. Installing Openpyxl through Pip requires the user to use a Windows program called Command Prompt.

If the user already had an existing version of Python 2.7 and did not do a new installation, the existing version of Python may not have Pip installed. If the existing version does not have Pip installed, the user will run into an error during Step 2.5. If this occurs, the user should try installing the default version of Python 2.7 using the directions provided in the previous sub-section, [1. Install Python 2.7](#).

### Steps:

- Step 2.1: Click on the Start menu (e.g., the Windows Logo Icon in the bottom-left corner of the computer screen, see [Figure 12](#)). In the Start menu, click on “Search for programs and files” (see [Figure 13](#)). In this box, type “Command Prompt”.
- Step 2.2: Typing “Command Prompt” into the search box should change the menu to look similar to [Figure 14](#). Click on the listing for “Command Prompt” under “Programs”.
- Step 2.3: Clicking on Command Prompt should open a window that looks similar to the one illustrated in [Figure 15](#) (on the previous page). What is printed in the window when the user opens it may vary by computer. For the purposes of installing Openpyxl, it should be fine if what is displayed in the user’s window differs from what is illustrated in the figure.
- Step 2.4: In the Command Prompt window, the user should type the following:
 

```
C:\Python27\Scripts\pip.exe install openpyxl==2.0.5
```

Note: The only spaces are between “exe” and “install”, and between “install” and “openpyxl”.

[Figure 16](#) illustrates how this command looks on the Windows computer used for this guide. Once the user has typed the command, the user should press Enter (or Return).
- Step 2.5: After the user presses Enter, Openpyxl should start to download. If the user installed Python 2.7 following the steps in the previous sub-section, this command should work and the result of pressing Enter should look something like the output in [Figure 17](#) (on the following page), with the end result being the successful installation of Openpyxl.

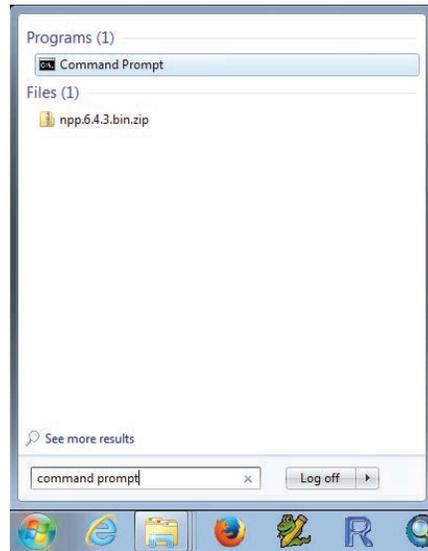
**Figure 12. Step 2.1: Windows Start Menu Icon**



**Figure 13. Step 2.1: Search for Program**



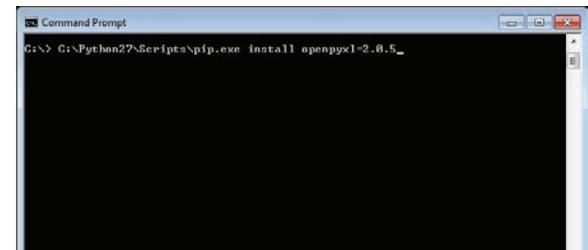
**Figure 14. Step 2.2: Search Results**



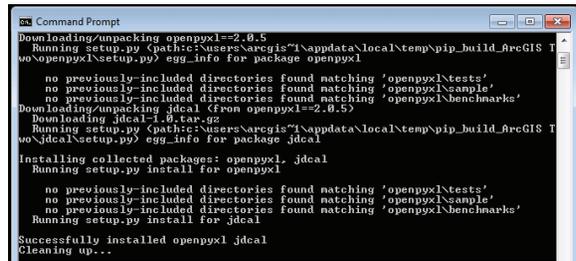
**Figure 15. Step 2.3: Open Command Prompt**



**Figure 16. Step 2.4: Command to Install Openpyxl**



**Figure 17. Step 2.5: Installation of Openpyxl**



**Troubleshooting:** If the output in the Command Prompt window does not look like that displayed in Figure 17, (e.g., the user does not see something along the lines of “Successfully installed openpyxl”, “Cleaning up...”), the user may need to reinstall the default installation of Python 2.7. The user should try deleting their current version of Python 2.7, located in the “My Computer” folder (i.e., the “C” folder), and then reinstalling a new, default installation of Python 2.7 by following the steps listed in the previous sub-section, 1. [Install Python 2.7](#). However, if the user uses Python for a different project, the user should contact the appropriate parties to make sure deleting the version of Python the user has installed doesn’t cause other problems.

## 6. SET UP A NEW SCENARIO

If the user wants to run a new scenario (e.g., entitled “Scenario 1” in this guide) where the user may see what happens under different model assumptions, the user may create a new folder in the *scenarios* folder. This guide uses the name “Scenario 1” as an example. The user may rename this folder any name they want. Figure 18 shows where in the folder structure the user should create the new folder. The easiest way to set up a new scenario is to copy

the *Example Scenario* folder and then rename the copy *Scenario 1* (or any other scenario name). The user may then open “HCAS Inputs 2015.xlsx” in the *inputs* folder and change assumptions and inputs in that workbook. The user should then resave it, and run the HCAS Python model. Figure 19 shows all of the required input files and their placement within the *Scenario 1* folder. While the actual folder names in the *scenarios* folder may change (e.g., the folder names in the *scenarios* folder in Figure 18 could just as easily be “Final Final” or “Scenario One”), it is important that the user does not change the file names in the *inputs*

**Figure 18. Add a New Scenario Folder**

Name	Kind
2015 Oregon HCAS Model	Folder
code	Folder
processed scenarios	Folder
scenarios	Folder
Example Scenario	Folder
Scenario 1	Folder
template_outputs	Folder
README.rtf	Rich Text Document

**Figure 19. Add New Scenario Input Files**

Name	Kind
Example Scenario	Folder
Scenario 1	Folder
inputs	Folder
HCAS Inputs 2015.xlsx	Microsoft Excel workbook
txt_2015	Folder
AxleShares.txt	Plain Text Document
BasicSharePeak.txt	Plain Text Document
Bonds2003-2005.txt	Plain Text Document
Bonds2005-2007.txt	Plain Text Document
Bonds2007-2009.txt	Plain Text Document
Bonds2009-2011.txt	Plain Text Document
Bonds2011-2013.txt	Plain Text Document
Bonds2013-2015.txt	Plain Text Document
DeclaredOperating.txt	Plain Text Document
DeclaredRegistered.txt	Plain Text Document
PaveFactors.txt	Plain Text Document
PCEFactors.txt	Plain Text Document
SeedData.txt	Plain Text Document
SimpleFactors.txt	Plain Text Document

folder (i.e., the user should not change the names of the input text files or the name of the inputs Excel workbook).

When the user runs the HCAS Python model, the model will create an outputs folder that it will fill with all of the model outputs. Figure 20 shows the file structure and files that will be created when the model is run. Section 7, [Run the HCAS Python Model](#) describes how to run the model.

Once the user is satisfied with the model outputs, the user may move the *Scenario 1* folder from the *scenarios* folder to the *processed scenarios* folder. Figure 21 shows the result of moving the *Scenario 1* folder to the *processed scenarios* folder.

**Figure 20. New Scenario Output Files**

Name	Kind
Example Scenario	Folder
Scenario 1	Folder
inputs	Folder
outputs	Folder
HCAS Outputs 2015 Scenario 1.xlsx	Microsoft Excel workbook
txt_2015	Folder
Adjust10-26.txt	Plain Text Document
AllocatedCosts_bond.txt	Plain Text Document
AllocatedCosts_federal.txt	Plain Text Document
AllocatedCosts_local-federal.txt	Plain Text Document
AllocatedCosts_local-other.txt	Plain Text Document
AllocatedCosts_local-state.txt	Plain Text Document
AllocatedCosts_other.txt	Plain Text Document
AllocatedCosts_state.txt	Plain Text Document
Bonds2015-2017.txt	Plain Text Document
DeclaredPaveFactors.txt	Plain Text Document
FlatFeeReport.txt	Plain Text Document
SubsidiesbyVehClass.txt	Plain Text Document
VMTMaster.txt	Plain Text Document
MissingPavementFactors.log	Log File

**Figure 21. Move New Scenario Folder**

Name	Kind
code	Folder
processed scenarios	Folder
Scenario 1	Folder
scenarios	Folder
Example Scenario	Folder
template_outputs	Folder
README.rtf	RTF Document

## 7. RUN THE HCAS PYTHON MODEL

The steps outlined in this section may need to be repeated each time the user wants to run a scenario through the 2015 Oregon HCAS Model.

If the user does not have an IDLE window open, the user should start at 1. [Open IDLE](#). If the user already has an IDLE window open, the user should start at 2. [Run the HCAS Python Model](#).

### I. OPEN IDLE

Once the user has Python and Openpyxl installed, the user is ready to run the HCAS Python model. The most straightforward way to run the HCAS Python model is through a graphical user interface (GUI) for Python. IDLE is a standard Python GUI that works on Windows, Mac OS X, and Unix.<sup>3</sup> IDLE should be automatically installed when the user installed a new version of Python 2.7 by following the steps in [Section 5, Install Python and Openpyxl](#).

#### Steps:

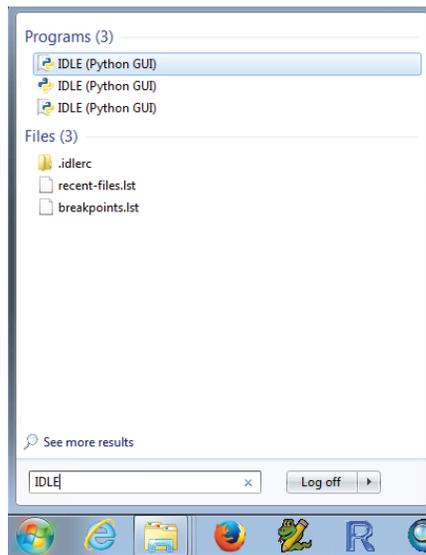
- Step 1.1: Click on the Start menu (e.g., the Windows Logo Icon in the bottom-left corner of the computer screen). In the Start menu, click on “Search for programs and files” (see [Figure 22](#)). In this box, type “IDLE”.

**Figure 22. Step 1.1: Search for IDLE**

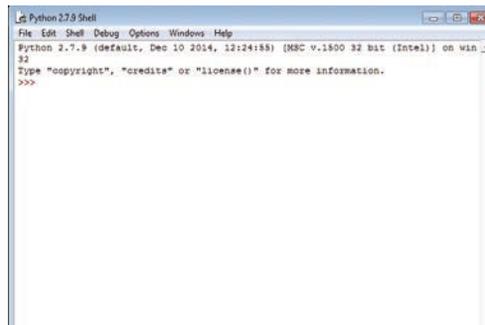


- Step 1.2: Typing “IDLE” into the search box should change the menu to look something like what is illustrated in [Figure 23](#). There may be more than one listing for IDLE, as illustrated in the figure. Click on any one of the listings for “IDLE” under “Programs”.
- Step 1.3: Clicking on IDLE should open a window that looks similar to the one illustrated in [Figure 24](#).

**Figure 23. Step 1.2: Search Results for IDLE**



**Figure 24. Step 1.3: Open IDLE**



## 2. RUN THE HCAS PYTHON MODEL

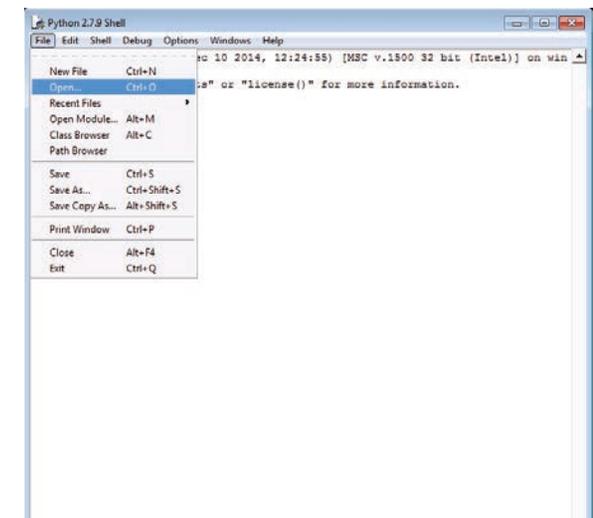
Once the user has an IDLE window open (the result of completing the steps in the previous sub-section, 1. [Open IDLE](#)) the user is ready to run the HCAS Python model.

Make sure there is a window open like the one displayed in [Figure 24](#) (if there is not, go back to the previous sub-section, 1. [Open IDLE](#) , and follow those steps). The following lists steps to run the HCAS Python model, HCASModule.py, using IDLE.

#### Steps:

- Step 2.1: As illustrated in [Figure 25](#), click on the “File” menu icon in the top-right corner of the IDLE window. In the File drop down menu, click on “Open.”

**Figure 25. Step 2.1: Open a File in IDLE**



<sup>3</sup> Documentation and more in-depth instructions on how to use IDLE are available at: <https://docs.python.org/2/library/idle.html>.

- Step 2.2: Clicking on Open will make a new window pop up similar to the one illustrated in Figure 26. In this window, find the location on the user’s computer with the “2015 Oregon HCAS Model” folder (i.e., the unzipped model distribution folder, see Figure 1). Within this folder, click on the *code* subfolder, and then select “HCASModule.py”. In the window, click on “Open” in the bottom-left corner of the window (see Figure 26).

Figure 26. Step 2.2: Select File to Open

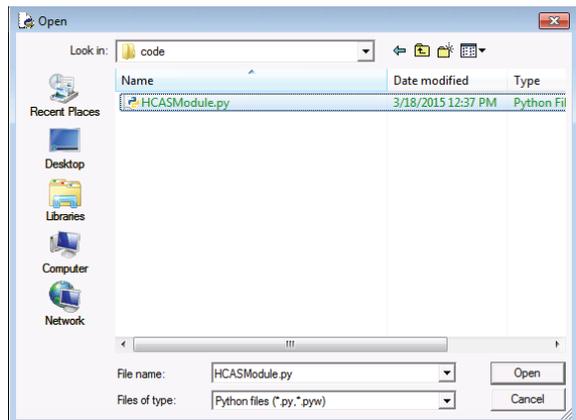
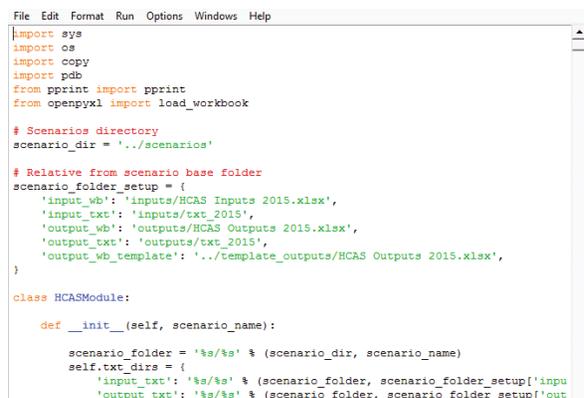


Figure 27. Step 2.3: Open the HCAS Python Model



- Step 2.3: Opening “HCASModule.py” will open a new window with the HCAS Python model code displayed. This window will look similar to the window illustrated in Figure 27. The user should not make any changes to the code displayed in this window.
- Step 2.4: Figure 28 illustrates how to run the HCAS Python model in IDLE. In the menu bar in the top of the IDLE window, click on the “Run” menu icon in the top-center of the IDLE window. In the Run drop down menu, click on “Run Module.”

- Step 2.5: Clicking on “Run Module” will open up a new IDLE window similar to the one illustrated in Figure 29. Initially, only the black text at the top of the window will show up. As the HCAS Python model runs, text in blue will gradually appear. The lines in blue tell the user the progress of the HCAS Python model and what point it is at in the calculations and model process.

The blue text may also provide some troubleshooting instructions for the user in case the HCAS Python model tries to open a file or folder and cannot find it.

- Step 2.6: The model has finished running shortly after “>>>” shows up in black text (see the last line in Figure 29). At this point, the user may go to the scenario’s folder (e.g., Scenario 1). In this folder, there will be an *outputs* folder where the user may examine the model outputs. If the user is satisfied with the model outputs, the user should move the scenario’s folder (*Scenario 1*) from the *scenarios* folder to the *processed scenarios* folder.

Note: If the user moves the scenario’s folder to the *processed scenarios* folder, but then wants to make other modifications to the scenario’s inputs and re-run the scenario, the user should move the scenario’s folder back to the *scenarios* folder and then repeat the steps in this section.

Figure 28. Step 2.3: HCAS Python Model

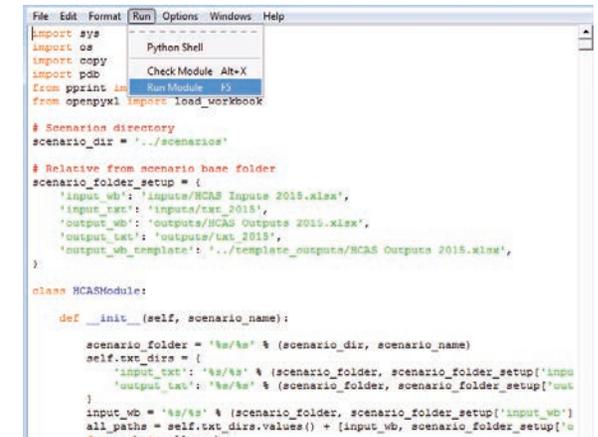
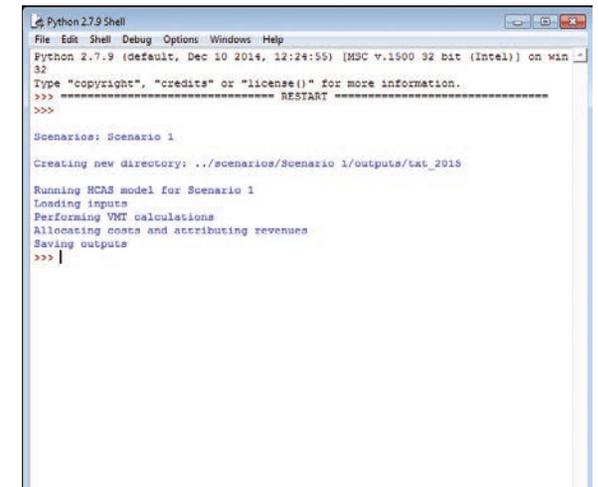


Figure 29. Step 2.5: IDLE Run Window



## 8. INPUT DATA AND DATA PREPARATION

This section describes the original data files and the data sources required to update the HCAS model. Many of these data files are obtained from sources within the Oregon Department of Transportation (ODOT) and are produced or adapted specifically for the Oregon HCAS. For each data set, the data files, sources for the data, and any pre-processing of the data outside of the model are described.<sup>4</sup> Appendix F provides a full list of the data sources and the original filenames.

### WEIGH-IN-MOTION DATA

**Source:** Portland State University/ODOT

Weigh-in-motion (WIM) sensors weigh every truck passing over multiple points on Oregon's freeway system and at other, non-freeway locations. WIM data provide a good description of the distribution of operating weights.

### Pre-Processing of WIM Data

The WIM data are used to calculate distributions of operating weight classes and numbers of axles for each declared weight (and number of axles for declared weights over 80,000 pounds). For each declared weight and axle category, calculate the distribution of WIM observations among vehicle operating weight classes and number of axles (coding 9 or more axles as 9). These data are used to create the *DeclaredOperating.txt* input text file.

The input file should have four columns: Declared (declared weight category identified by the lowest weight in the category, e.g.,

1, 10001, 12001, 14001,...), DeclaredAxles (declared number of axles; zero for declared weights up to 80,000 pounds), Operating (operating weight class), OperatingAxles (actual number of axles, but not more than 9), and Share (share of vehicles for the declared weight and declared axles category by operating weight and operating axles). For each declared weight and axles category, the sum of the shares in the table should equal one.

### HPMS DATA

**Source:** ODOT

The Highway Performance Monitoring System (HPMS) is a federal program that collects data from each state every year. Over the years, the number of data elements that must be reported has changed, but the data are still extremely useful in highway cost allocation and in developing pavement factors.

### Pre-Processing of HPMS Data

The entire HPMS data set is an input file for the NAPCAS model. The HPMS data are also used in the process of estimating distributions of VMT by functional class and ownership in the *VMT by FC* tab in the inputs workbook.<sup>5</sup>

To perform the data tabulation of the HPMS data for the *VMT by FC* tab, divide the HPMS section average annual daily traffic (AADT) by the section length in miles and multiply by 365 days to calculate the section VMT. Since HPMS is a sample, each sample section VMT is expanded by multiplying it by its section weight. A summary table of VMT by functional system and ownership is tabulated and pasted into the *VMT*

*by FC* tab such that the rows are the functional system, the column headings are ownership, and the cell entries are the sum of VMT.

### FEDERAL AND TRANSIT VMT DATA

#### FHWA Highway Statistics Data

**Source:** Office of Highway Policy Information, Federal Highway Administration, <http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm>

The Federal Highway Administration (FHWA) publishes an annual report called *Highway Statistics*. Data from tables VM-1 and VM-2 from Highway Statistics are used in the HCAS model for the base year VMT and VMT by FC. The Oregon row from Table VM-2, Functional Travel System Travel (Year) 1/Annual Vehicle-Miles, is pasted into the *VMT by FC* tab in the appropriate row. The Oregon row from Table MV-7, Publicly Owned Vehicles, is used in the *Federal VMT* tab. FHWA usually begins to release tables and chapters from *Highway Statistics* in late fall or winter of the following year. Use the *Highway Statistics* report corresponding to the study base year. If base year statistics are unavailable, use the most recent data that are available.

The appropriate rows from these tables should be pasted into the yellow-shaded cells in the inputs workbook where indicated on the *Federal VMT* and *VMT by FC* tabs.

#### GSA Federal Fleet Report Data

**Source:** U.S. General Services Administration, [www.gsa.gov/vehiclepolicy](http://www.gsa.gov/vehiclepolicy)

The *Federal Fleet Report* is an annual publication produced by the U.S. General Services Administration (GSA). The *Federal*

<sup>4</sup>For some data sources, screenshots of the inputs workbook are provided in this section.

<sup>5</sup> VMT by FC is the vehicle miles traveled (VMT) by the facility class (FC), where each facility class is defined by a functional class and ownership.

*Fleet Report* provides data on the number of federal vehicles and vehicle miles traveled by vehicle type and department or agency in the base year. These data are used in the *Federal VMT* tab as part of the federal vehicle class VMT calculations which help develop the *Base VMT* tab. The tables from the *Federal Fleet Report* used in the study are Table 2-5 (Passenger Vehicles), Table 2-6 (Trucks and Other Vehicles), and Table 4-2 (Average Miles Per Vehicle).

The *Federal VMT* tab lists the tables and rows from the *Federal Fleet Report* that should be pasted into the yellow-shaded cells on the tab.

**Transit VMT Data**

**Source:** Tri-Met, Lane Transit District, Salem-Keizer Cherriots Transit District

Transit bus VMT is updated on the *Transit VMT* tab with VMT information obtained by calling the three largest transit agencies in Oregon: Tri-Met, Lane Transit District, and Salem-Keizer Cherriots Transit District. Call each transit district to request information on the total calendar year VMT for buses by bus weight class for the base year. Enter this data directly into the yellow-shaded cells in the *Transit VMT* tab.

**MOTOR CARRIER DATA**

The Motor Carrier Transportation Division (MCTD) of ODOT produces data on truck registrations, WMT collections, and flat-fee collections. These data are cleaned and consolidated into a set of reports called Highway

Use Statistics. The cleaned, unconsolidated data are used in the study.<sup>6</sup>

**Motor Carrier Registrations Data**

**Source:** MCTD, ODOT

The Motor Carrier Registrations data are used to develop distributions of registered weights by declared weights for the *DeclaredRegistered.txt* input text file. For each declared weight category, the text file contains the share of vehicle registrations at a registered weight.

**Pre-Processing of the Motor Carrier Registrations Data**

The Motor Carrier Registrations data are used to develop the *DeclaredRegistered.txt* input text file. The share of vehicle registrations for the distribution of registered weights for each declared weight should be calculated from the count of registrations. The final processed table for the *DeclaredRegistered.txt* input text file should contain the declared weight, the registered weight, and the share of registrations at that declared weight.

**Flat Fee Collections Reports**

**Source:** MCTD, ODOT

The Flat Fee Collections Reports are used to calculate the Flat Fee VMT for the *MCTD VMT* tab which links to the *Base VMT* tab. The data are also used to estimate VMT per month and axle shares for the *Rates* tab.

**Pre-Processing of the Flat Fee Collections Reports**

A summary table of the monthly miles and count of the monthly reports from the Flat Fee Collections Reports should be created using a series of pivot tables. The pivot table rows are commodity, weight class, and axle count. A “mile\_non\_zero” indicator can be created and used in the page fields so that the pivot table can produce results for all observations or for records where miles are non-zero. In the model calculation, the log truck flat fee analysis includes an adjustment for log truck empty miles to account for the log hauler option of declaring a lower weight when their trailer is empty and stowed above the tractor unit. Because the analysis will account for the empty log truck

**Figure 30. Flat Fee**

	A	I	J	K
1	Flat Fee Miles			
2	Weight	Logs	Dump	Chip
3	26,001	0	10,935	0
4	28,001	0	0	0
5	30,001	0	0	0
6	32,001	0	0	0
7	34,001	0	0	0
8	36,001	0	0	0
9	38,001	0	0	0
10	40,001	0	0	0
11	42,001	0	0	0
12	44,001	0	300	0
13	46,001	0	105,713	0
14	48,001	0	0	0
15	50,001	0	14,124	0
16	52,001	0	0	0
17	54,001	0	42,344	0
18	56,001	0	73,174	0
19	58,001	0	0	0
20	60,001	0	0	0
21	62,001	0	0	0
22	64,001	0	12,960	0
23	66,001	0	0	0
24	68,001	0	0	0
25	70,001	0	0	0

<sup>6</sup>Weight class and axle class are two important variables used in the HCAS model for defining vehicle classes. HCAS weight classes are shown in the *Codes* tab in the inputs workbook. Basic vehicles are those vehicles weighing less than 10,001 pounds. For vehicles from 10,001 to 200,001 pounds, weight classes are defined in 2,000-pound increments, (e.g. 10,001, 12,001, ...80,001, 82,001...200,001). The vehicle weight recorded in the original data source is used to assign the record to a HCAS weight class. For a weight recorded in pounds, subtract one from the entered weight, divide by 2,000, truncate or round to the decimal point, then multiply by 2,000 and add one (e.g., Round((Weight-1)/2000,0)\*2000+1 in Excel). HCAS axle classes are zero, five, six, seven, eight or nine (or more). If the weight class is under 80,001, the axle class is zero. For 80,001 and above, a record with five or fewer reported axles is assigned to axle class five, and nine or more axles are assigned to axle class nine. If the reported axle count is six, seven, or eight, the axle class is set equal to the reported number of axles.

VMT, the input log truck VMT must be correctly entered at their fully loaded weights. Log trucks reported at weights under 56,000 pounds are assumed to be a data entry or report error (i.e., reported as the empty or average operating weight when the weight reported should be the loaded weight). Thus, log trucks with a reported weight under 56,000 pounds should be reassigned to a higher weight class. If the plate number for the under-56,000-pounds record is also reported at a higher weight, the lower weight record is entered at the higher weight class. Log truck records entered at weights under 56,000 pounds that are not reassigned to a higher weight class are excluded.

For the Flat Fee Miles table (see [Figure 30](#) on the previous page) in the *MCTD VMT* tab, the miles reported in the Flat Fee Collections Reports are summed for each commodity and axle class and then the number of non-zero records and total number of records are counted.

For the *Rates* tab, create a pivot table or summary table results using the Flat Fee Collections Reports data. The records where miles are non-zero (“non-zero miles”) are used to calculate the average VMT per month and the axle share of VMT for each weight class.

**Road Use Assessment Fee Data**

*Source:* MCTD, ODOT

The road use assessment fee (RUAF) data are the records from the vehicles paying the RUAF at weight classes of 96,001 pounds and above. Each RUAF record contains an ID number, issue date, axles, weight, miles, and tax. The RUAF data are tabulated to determine the VMT by RUAF vehicles by weight and axle class, which are then pasted into RUAF table in the *MCTD VMT* tab (see [Figure 31](#)).

**WMT Collections Reports**

*Source:* MCTD, ODOT

The WMT Collections (or Payments) Reports are pre-processed and used to develop the *MCTD VMT* tab and determine the VMT for the various WMT vehicle classes.

**Figure 31. RUAF**

	M	N
1	RUAF	
2	Weight	Miles
3	26,001	0
4	28,001	0
5	30,001	0
6	32,001	0
7	34,001	0
8	36,001	0
9	38,001	0
10	40,001	0
11	42,001	0
12	44,001	0
13	46,001	0
14	48,001	0
15	50,001	0
16	52,001	0
17	54,001	0
18	56,001	0
19	58,001	0
20	60,001	0
21	62,001	0
22	64,001	0
23	66,001	0
24	68,001	0
25	70,001	0
26	72,001	0
27	74,001	0
28	76,001	0
29	78,001	0
30	80,001	0
31	82,001	0
32	84,001	0
33	86,001	0

**Figure 32. WMT**

	A	B	C	D	E	F	G
1	Weight-Mile Tax						
2	Weight	Any Axles	5 Axles	6 Axles	7 Axles	8 Axles	9 Axles
3	26,001	2,271,506	0	0	0	0	0
4	28,001	3,795,889	0	0	0	0	0
5	30,001	9,240,146	0	0	0	0	0
6	32,001	21,789,619	0	0	0	0	0
7	34,001	4,445,506	0	0	0	0	0
8	36,001	2,388,576	0	0	0	0	0
9	38,001	3,361,092	0	0	0	0	0
10	40,001	3,386,116	0	0	0	0	0
11	42,001	3,252,140	0	0	0	0	0
12	44,001	31,334,477	0	0	0	0	0
13	46,001	12,253,217	0	0	0	0	0
14	48,001	14,183,916	0	0	0	0	0
15	50,001	13,504,875	0	0	0	0	0
16	52,001	24,104,208	0	0	0	0	0
17	54,001	23,342,277	0	0	0	0	0
18	56,001	8,185,015	0	0	0	0	0
19	58,001	7,746,649	0	0	0	0	0
20	60,001	1,430,298	0	0	0	0	0
21	62,001	2,404,824	0	0	0	0	0
22	64,001	10,091,062	0	0	0	0	0
23	66,001	2,492,802	0	0	0	0	0
24	68,001	5,053,489	0	0	0	0	0
25	70,001	3,061,798	0	0	0	0	0
26	72,001	2,182,376	0	0	0	0	0
27	74,001	5,173,539	0	0	0	0	0
28	76,001	939,767	0	0	0	0	0
29	78,001	974,854,767	0	0	0	0	0
30	80,001	0	6,960,368	229,814	240,098	24,347	12,145
31	82,001	0	8,411,192	809,017	86,661	54,198	8,009
32	84,001	0	5,948,393	4,795,056	330,389	49,890	6,290
33	86,001	0	2,023,395	11,950,570	914,216	89,437	2,964

*Pre-Processing of the WMT Collections Reports*

The size of the WMT Collections Report data set requires that the data pre-processing take place outside of the HCAS model.

Assign all of the records in the WMT Collections Report data to a weight class and axle class using the HCAS weight class and axle class categories. Then, create a summary table that has the sum of the miles traveled for the HCAS weight and axle class categories from the WMT Collections Report data. This summary table is then pasted into Weight-Mile Tax table in the *MCTD VMT* tab (see [Figure 32](#)).

### VMT ESTIMATES AND FORECAST

**Source:** Financial and Economics Analysis Unit, ODOT Financial Service Branch

The Financial and Economic Analysis Unit of ODOT’s Financial Services Branch produces VMT estimates for use in its estimation of revenues for budgeting. These become available at the same time as the Agency Request Budget, which has been at the end of August.

The ODOT VMT estimates and forecast are used to determine the base year to model year VMT growth rate for light, medium-heavy, and heavy vehicle groups. The data do not require pre-processing and should be pasted into the yellow-shaded cells on the *VMT Growth* tab so that the new base year and forecast year match the base year and forecast year labels. The base-year VMT from the ODOT forecast are used to control total VMT for light and medium-heavy vehicle classes in the *Base VMT* tab.

### DMV VEHICLE REGISTRATIONS

**Source:** Department of Motor Vehicles, Request by ODOT Financial Services

The DMV registrations data are used to build the estimates of VMT by weight class and tax class for the base year for certain vehicle tax classes. For the 2015 HCAS, ODOT Financial Services was granted permission to obtain de-identified registration records from DMV.

#### Pre-Processing of the DMV Registrations Data

Due to the size of the DMV registrations data, pre-processing of the registrations takes place outside of the HCAS model.

Two summary tables created from the DMV registrations are used to update the model: a summary table of motor home registrations by vehicle length, and a summary table of other, special categories of vehicle registrations by fuel type and weight class.

The DMV registrations data are used to create a summary table of vehicle registrations by fuel type and weight class for the following vehicle tax classes: Commercial Trucks (10,001 to 26,000 pounds), Tow Trucks, Farm Vehicles, Charitable Non-profit, and E-Plate (exempt). For this table, a weight class is assigned to each registration record by converting the registered vehicle weight to the corresponding HCAS weight class. Fuel type is available from the “motive power” field.

The license plate string is used to identify the vehicle tax class using the plate vehicle class designations (T for commercial truck, TW for tow truck, F for farm, CN for charitable/non-profit, or E for exempt; followed by numerals).

The summary table of DMV registrations data should be pasted into the yellow-shaded cells (columns F through O) in the left-most table on the *DMV-Other* tab (see [Figure 33](#)).

**Figure 33. DMV-Other**

	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Gas						Diesel & Other					Assumed Miles per Registration				
2	Weight Class	CN	E	F	T	TOW	CN	E	F	T	TOW	CN	E	F	T	TOW
3	1	101	33,123	1,973	854	102	51	14,096	517	855	308	10,000	13,000	3,000	0	15,000
4	10,001	132	37	458	1,856	28	75	40	378	2,137	74	10,000	12,000	3,000	19,000	15,000
5	12,001	89	31	223	779	23	44	32	231	1,561	92	10,000	12,000	3,000	19,000	15,000
6	14,001	197	44	404	1,134	34	88	134	468	3,265	161	10,000	12,000	3,000	19,000	15,000
7	16,001	21	8	266	399	9	32	30	373	1,942	108	10,000	12,000	3,000	19,000	15,000
8	18,001	18	4	462	315	9	65	46	718	1,957	172	10,000	12,000	3,000	19,000	15,000
9	20,001	10	2	182	111	3	17	34	266	471	31	10,000	12,000	3,500	19,000	15,000
10	22,001	7	5	353	186	1	23	8	395	675	51	10,000	12,000	3,500	19,000	15,000
11	24,001	24	10	767	675	27	128	63	1,373	5,813	659	10,000	12,000	3,500	19,000	15,000
12	26,001	6	3	348	8	0	41	10	244	24	1	10,000	11,000	3,500		15,000
13	28,001	3	5	315	6	0	21	86	339	25	0	10,000	11,000	3,500		15,000
14	30,001	3	2	210	1	0	30	49	326	15	0	10,000	11,000	3,500		15,000
15	32,001	0	1	56	3	0	34	42	290	35	0	10,000	11,000	3,500		15,000
16	34,001	0	1	44	2	0	11	29	119	18	0	10,000	11,000	3,500		15,000
17	36,001	0	2	16	0	0	11	65	50	13	0	10,000	11,000	3,500		15,000
18	38,001	0	2	42	0	0	8	17	155	7	0	10,000	11,000	3,500		15,000
19	40,001	2	1	31	0	0	1	3	49	7	0	10,000	11,000	4,000		15,000
20	42,001	0	3	100	0	0	1	5	128	0	0	10,000	11,000	4,000		15,000
21	44,001	1	0	130	1	0	3	3	569	18	0	10,000	11,000	4,000		15,000
22	46,001	0	1	81	3	0	6	7	593	20	0	10,000	11,000	4,000		15,000
23	48,001	0	0	72	1	0	5	6	562	11	0	10,000	11,000	4,000		15,000
24	50,001	0	0	7	0	0	2	2	201	7	0	10,000	11,000	4,500		15,000

**Figure 34. Motorhomes**

	A	B	C
1	<b>Motorhomes</b>		
2	<b>Length</b>	<b>Count</b>	<b>Weight Class</b>
3	23	2,163	10,001
4	24	2,407	10,001
5	25	1,096	12,001
6	26	1,933	12,001
7	27	2,207	14,001
8	28	1,609	14,001
9	29	2,129	14,001
10	30	2,351	14,001
11	31	2,751	16,001
12	32	2,396	16,001
13	33	1,625	18,001
14	34	2,562	18,001
15	35	1,927	22,001
16	36	2,335	24,001
17	37	1,181	26,001
18	38	1,241	28,001
19	39	591	30,001
20	40	2,485	30,001
21	41	83	30,001
22	42	346	30,001
23	43	118	30,001
24	44	30	30,001
25	45	291	30,001
26			
27	<b>VMT per motorhome</b>	<b>3,988</b>	

Motorhome registrations data do not include vehicle weight, so registrations are tabulated by vehicle length and assigned a HCAS weight class based on their reported vehicle length. The summary table is pasted into the Motorhomes table in the *DMV VMT* tab in the inputs workbook (see [Figure 34](#)).

**PAVEMENT FACTORS**

*Source:* RD Mingo & Associates

RD Mingo & Associates produce Oregon-specific pavement factors using the Oregon HPMS submittal data in the new 2010 National Pavement Costs Model (NAPCOM). Pavement factors are used to update *PavementFactors.txt* input file and the pavement allocators in the *Policy* tab. Minimal processing of the pavement

factors data may be necessary to get the pavement factors into the correct format for *PavementFactors.txt*.

**ESTIMATED AVERAGE BASIC-VEHICLE MPG**

*Source:* Financial and Economics Analysis Unit, ODOT Financial Services Branch

The ODOT revenue forecast and budget-development process incorporates assumptions about fuel consumption per mile that are developed from data from Global Insight and other sources. These fuel consumption assumptions are used to inform the user choice of parameters on the *Gas and Diesel* table in the *General* tab in the inputs workbook. While the fuel consumption per mile assumptions provided by ODOT are not direct inputs into the model, the user-specified assumptions regarding the implied MPG on the *Gas and Diesel* table in the *General* tab should be generally consistent with the assumptions made by ODOT.

**EXPENDITURE AND REVENUE DATA**

**Local Government Revenues and Expenditures**

*Source:* ODOT-conducted Local Roads and Streets Survey

Prior-fiscal-year (corresponding to the model year) revenues and expenditures by local governments come from the Local Roads and Streets Survey (LRSS) compiled by ODOT.

Paste the LRSS data into the *Local Costs* tab and the formulas in that tab will produce estimates of future expenditures by work type and funding source.

**Budgeted Non-Project Expenditures**

*Source:* ODOT Agency Request Budget

Budgeted non-project expenditures come from spreadsheets used to develop the Agency Request Budget and are required to update the *Non-Project Costs* tab. These data are available around the end of August and are completed by the ODOT Finance Section. The Highway Programs Office provides the breakdown of non-project maintenance costs by maintenance work type.

The non-project expenditure data do not require any pre-processing. The non-project expenditure data are pasted into the *Non-Project Costs* tab.

**Project Expenditure Data**

*Source:* ODOT Financial Services

Project cost information is collected from several sources. The ODOT Cash Flow Projection system tracks expenditures by work category for each project per month. Upon request, project expenditure files are produced that contain data for all projects with expected expenditures in the upcoming biennium. ODOT Finance then matches these projects to the Project Control System (PCS) to obtain additional data about the nature of the projects, particularly the project funding sources and project work types. For bridge projects, additional research is conducted using information in the PCS files, the Oregon Bridge Log, or correspondences with ODOT bridge section staff to determine relevant characteristics of the bridges involved so that the expenditures may be assigned to bridge types. Expenditures on different bridge types

are allocated using different factors. Project expenditures data are requested when the Agency Request Budget data become available (generally in August or September) so that the project data are consistent with the budget.

### ***Pre-Processing of Project Expenditure Data***

Given the number of different sources, some in non-standardized formats, used to create the project expenditures input data, there is no formalized method for processing and developing the project costs table. The general steps for processing and creating the project costs table are the following:

1. Identify projects with expenditures during the study period from Cash Flow Projections
2. Assign a functional class to the project using information in the PCS.
3. Determine the share of project funding from each funding source
4. Determine the project HCAS work type(s) using the project information and/or the ODOT-specified work types
5. If the project has more than one work type, determine the share of project expenditures by work type
6. For each bridge project work type, assign a bridge type

Using the list of projects in the Cash Flow Projection and PCS, create a list of projects with expenditures in the study period.

Assign a functional class to each project. If a functional class is included in the project location information, validate that the functional

system is a valid FHWA functional system or HCAS facility class. Projects are assigned a functional class based on the project funding sources if functional class is not provided. Functional system of zero is the default for an unknown functional system.

For each project, determine the share of project expenditures by funding source. Project expenditure shares by funding source reflect the total project funding, not necessarily the expenditures during the study period. Shares or dollar amounts by funding source are provided in the PCS data. Funding source should be entered as federal, state, bond, or other. Make sure the funding source is spelled correctly and is not capitalized.

Use the PCS project work type(s) and project description (SXYR Work Description) to assign HCAS work type(s) to the project. The project may have up to three work types. ODOT may have already listed three project work types and the work type funding shares in PCS. The analyst should review the ODOT-assigned work types and then assign the appropriate HCAS work type. The share of total project costs associated with each work type must be entered when multiple work types are assigned. Only assign multiple work types when the share of total project costs can be identified for each work type.

Bridge types are assigned to all projects. If the project is not a bridge project, then the bridge type can be entered as zero. Zero is also used when the bridge type is unknown. The bridge length and number of spans determine the bridge type. When multiple bridge types are

being built or replaced in a single project, the bridge types may be entered separately, as if they were different work types, but using the same work type code. For example, if a project is a bridge bundle project replacing a single span bridge and a multi-span bridge, the bridge replacement work type would be assigned twice to the project, once for the single span bridge type and once for the multi-span bridge type. Again, the project can only have up to three work type/bridge type combos, and the share of total project funding must be identified for each work type/bridge type when broken out separately. Lists of work types and bridge types are located in the *Codes* tab in the inputs workbook.

The bridge length and spans may be reported in the PCS files, or the bridge number can be used to look up the bridge characteristics in the Oregon Bridge Log. The Oregon Bridge Log<sup>7</sup> will likely display the former bridge type in the case of bridge replacements. If the project is a bridge replacement, it may be necessary to contact the ODOT Bridge Section to find out information on the new bridge type.

For the 2015 HCAS, the project expenditure file was first created by working in a file where each project was a single record with columns for funding sources, funding source project cost share, functional class, work types, work type project cost share, bridge types, and total project amount. Once all of the funding source, work type, and bridge type data are entered, make sure that the entered data are valid and that the funding source and work type shares sum to 100 percent. Also make sure that the project expenditure is positive.

<sup>7</sup> The Oregon Bridge Log is an annual ODOT publication. The Oregon Bridge Log does not contain information on covered bridges. Most covered bridge projects are maintenance projects (on the covered structure); most covered bridges are single spans less than 125 feet.

The project expenditure data are then used to create the table of project expenditures by funding source and work type for the *Project Costs* tab. Because a project may have up to four funding sources and up to three work types, each project can potentially be turned into twelve separate entries in the *Project Costs* table. Paste the final project costs table into the *Project Costs* tab in the inputs workbook using the format shown in [Table 1](#).

[Table 1](#) displays an example of the *Project Costs* tab entries for a project that has three funding sources (state, federal, and other) and three work types (20, 21, and 41). The “Dollars” column is produced by multiplying the total project expenditures in the biennium by the fund source share and work source share. The key number is included for project identification but is not read into the model.

**Budgeted Revenue Control Totals**

**Source:** Financial and Economics Analysis Unit, ODOT Financial Services Branch

Budgeted revenue control totals come from spreadsheets used to develop the Agency Request Budget by the Financial and Economics Analysis Unit of the ODOT Financial Services Branch. These data are usually available at the end of August before the upcoming biennium.

The data in these spreadsheets are pasted into the yellow-shaded cells on the *Revenue Forecast* tab in the inputs workbook. Gross revenue amount by revenue source is linked to the appropriate revenue control total on the *Revenue Forecast* tab.

**Current-Law Tax Rates and Fee Schedules**

**Source:** Oregon Revised Statutes, or the ODOT DMV and MCTD websites

Current-law fuel tax rates, WMT rates, registration and title fees, and other vehicle- and road-use-related fees may be obtained from Oregon Revised Statutes and Oregon Administrative Rules. The rates and fee schedules can also be found at the ODOT Department of Motor Vehicles (DMV) and Motor Carrier Transportation Division (MCTD) websites. The WMT Schedule A and B tables can be found at the MCTD website, where the WMT rates are calculated for each weight class and axle combination for Table B.

Rates must be converted to the proper unit for each revenue instrument, otherwise no calculations or processing is required. Update the current tax rates if changes have been made in the Oregon Revised Statutes in the *Rates* tab in the inputs workbook.

**9. INPUT TEXT FILES**

This section describes the input text files used to recalculate the model. The user may update some of the input text files, however some files are carried forward to future studies without modification. Each input text file is listed below, followed by a description of how the file is used, the file contents, and how to update the file.

**AxleShares.txt**

This file contains the distribution of VMT by number of axles for each weight class. These shares change little from year to year and do not need to be updated every biennium. The source is the weigh-in-motion data.

**BasicSharePeak.txt**

This file contains the share of VMT during the peak hour of the day by functional class that are by basic vehicles.<sup>9</sup> These shares change little from year to year and do not need to be updated every biennium. The source is 24-hour automatic traffic recorder data from ODOT.

**Table 1. Example of Project With Multiple Work Types and Funding Sources**

Funding	Work Type	Functional Class	Bridge Type	Dollars	Key Number
state	20	0	0	164,498	K16239
state	21	0	0	65,178	K16239
state	41	0	0	80,697	K16239
federal	20	0	0	307,266	K16239
federal	21	0	0	121,747	K16239
federal	41	0	0	150,734	K16239
other	20	0	0	190,733	K16239
other	21	0	0	75,573	K16239
other	41	0	0	93,567	K16239

<sup>9</sup>For this purpose, we define the peak hour of the day as the hour with the most VMT.

**Bonds**

- *Bonds2003-2005.txt*
- *Bonds2005-2007.txt*
- *Bonds2007-2009.txt*
- *Bonds2009-2011.txt*
- *Bonds2011-2013.txt*
- *Bonds2013-2015.txt*

These files contain the prior allocated bonds from the 2003, 2005, 2007, 2009, 2011, and 2013 studies. The prior allocated bonds are read into the model and used in the class method that performs the bond cost allocation calculations. The file contents are the prior allocated bond expenditures (dollars) by weight class and axles. These files are not updated.

**DeclaredOperating.txt**

This file contains a distribution of operating weights for each declared weight from the weigh-in-motion data. The *DeclaredOperating.txt* data are used to build the pavement factors for each row of the VMT data in the VMT calculations of the model.

**DeclaredRegistered.txt**

This file contains a distribution of registered weights for each declared weight from the Motor Carrier Registrations data. The *DeclaredRegistered.txt* data are used to attribute registration and title fee revenues.

**PaveFactors.txt**

Contains the responsibility shares for flexible and rigid pavement costs by weight class and number of axles. This file is produced by Roger Mingo using the HPMS submission and weigh-in-motion data in the NAPHCAS-OR model.

**PCEFactors.txt**

This file contains the passenger-car equivalents (by weight class and number of axles) on regular, uphill, and congested roadways as estimated by Battelle for the most recent (1997) federal HCAS. This file is not updated.

**SimpleFactors.txt**

This file contains vectors of ones and zeros that help the model select the appropriate VMT for cost allocation. For example, for a cost allocated on over-106,000-pound VMT, the model will isolate the proper VMT records by applying a simple factor. In this case, a vector containing zeros for all weight classes except those above 106,000 pounds is applied to the VMT master. This file does not need to be updated for new studies unless the allocators are changed.

**SeedData.txt**

This file contains an initial guess as to the distribution of VMT by weight class, functional class, ownership, and number of axles. It does not need to be updated.

## 10. INPUTS WORKBOOK

This section provides a tab-by-tab explanation of the tabs in the input workbook. One input Excel workbook must be included in the scenario's *inputs* folder ("HCAS Inputs 2015.xlsx") for the processing of input data. The input workbook is read in when the HCAS model is run in Python. The majority of the required calculations and data tables are automatically updated when the yellow-shaded input cells are modified.

After updating the data and assumptions in the input tabs, check that the named ranges in the HCAS Model workbook are defined to include the full range of input data. To view and change a named range, go to the *Insert* menu, and select the *Name* option. From the *Name* menu, select the *Define* option. In the window that pops up, select the named range, and review and change (if necessary) the *Refers to* cell references.

**SET UP BASE VMT**

In the 2013 HCAS study, the *Base VMT* tab in the primary inputs workbook was developed using a supplemental Base VMT workbook. In the 2015 HCAS study, the *Base VMT* tab and the tabs that it links to it were consolidated into the main inputs workbook, "HCAS Inputs 2015.xlsx". The *Base VMT* tab is built using *DMV VMT*, *MCTD VMT*, *Federal VMT*, and *Bus VMT* tabs.

For the 2015 HCAS model, the approach for calculating the base VMT was formalized with the intermediate calculations performed in other VMT tabs in the main inputs workbook. To the extent possible, this allows the user to see the steps from the raw, original data to the detailed base-year VMT table. The following is a tab-by-tab explanation of the data and calculations that build the *Base VMT* tab. Some tabs were already discussed in the section, [Section 8, Input Data and Data Preparation](#).

**MCTD VMT**

The *MCTD VMT* tab contains calculations and data related to flat fee VMT, WMT VMT, and RUAUF. The pre-processing steps for those data are described and illustrated in [Section 8, Input Data and Data Preparation](#).

**Bus VMT**

The *Bus VMT* tab contains transit bus VMT and school bus VMT.

**Transit**

The columns B through H in the *Bus VMT* tab provide estimates of transit bus VMT in Oregon. Transit VMT estimates developed in 2005 are updated by scaling the transit district VMT by the change in the VMT for the three largest transit districts in Oregon.

Transit bus VMT is updated on the *Transit VMT* tab with VMT information from the three largest transit agencies in Oregon: Tri-Met, Lane Transit District, and Salem-Keizer Cherriots Transit District. To update this tab, the transit bus VMT by weight class for Tri-Met, Lane Transit District, and Salem-Keizer Transit District are collected for the base year (yellow-shaded input cells). The change in VMT for these three transit districts is used to adjust the 2005 transit VMT estimates.

**School Bus**

The columns K and L in the *Bus VMT* tab contain the estimates of school bus VMT in Oregon. School bus VMT by weight class and fuel type from 1999 is the base VMT distribution for the school bus VMT estimates. The Department of Education (DOE) estimate of total school bus VMT for 2006 is used as the control total for updating the VMT. The 2006 school bus VMT is distributed across weight classes using the school bus VMT distribution from 1999. School bus registrations by fuel type (gasoline or diesel) from the *DMV-Other* table is applied to the 2006 school bus VMT to determine the fuel-type split for the school bus VMT.

**Federal VMT**

In the 2015 HCAS, what was previously spread across three tabs (*Federal*, *Federal Weight Class Spread* and *Federal Summary*) in the 2013 HCAS is consolidated into one tab, *Federal VMT*.

**Federal**

Paste the indicated table rows from the FHWA *Highway Statistics* (Table MV-7) and the GSA *Federal Fleet Report* into the yellow-shaded cells in the Federal table on the *Federal VMT* tab (see [Figure 36](#) on the following page). The input data the *Federal* table are used with the *Federal VMT Spread* table to calculate the *Federal Summary VMT* table. It is important that the input data are pasted into the exact cells as indicated by the row and column headings because the cells are referenced in the VMT calculations at the bottom of the *Federal VMT* tab. The calculations at the bottom of the tab aggregate the various reported vehicle types and classes to calculate total federal VMT for buses, medium heavy trucks, and heavy trucks.

**Figure 35. Bus VMT**

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Bus VMT by Area and Assumed Shares										Bus VMT by Type		
2	Weight	TriMet	LTD	Salem-Keizer	Rogue Valley	Lincoln	Sunset Empire	Klamath Basin	Assumed School Shares		Gas School Buses	Diesel School Buses	Diesel Transit Buses
3	10,001	0	0						0.0030		37,799	161,144	0
4	12,001	0	0	0	0	0	0	0	0.0656		831,579	3,545,154	0
5	14,001	0	0	0	0	0	0	0	0.0048		60,479	257,830	0
6	16,001	0	0	0	0	0	0	0	0.0036		45,359	193,372	0
7	18,001	0	0	867,024	0	0	0	0	0.0042		52,919	225,600	867,024
8	20,001	0	0	0	0	0	0	0	0.0418		529,187	2,256,006	0
9	22,001	0	0	0	0	0	0	0	0.0585		740,862	3,158,410	0
10	24,001	524,645	0	0	0	0	0	0	0.2649		3,356,556	14,309,529	524,645
11	26,001	13,267,843	0		635,726	325,000	580,400	298,630	0.1259		1,595,120	6,800,250	15,107,599
12	28,001	8,219,164	0	0	0	0	0	0	0.1169		1,481,723	6,316,820	8,219,164
13	30,001	694,333	0	0	0	0	0	0	0.1712		2,169,666	9,249,628	694,333
14	32,001	0	0	0	0	0	0	0	0.0477		604,785	2,578,294	0
15	34,001	0	0	0	0	0	0	0	0.0901		1,141,532	4,866,530	0
16	36,001	0	0	0	0	0	0	0	0.0012		15,120	64,458	0
17	38,001	0	2,472,626	1,269,372	0	0	0	0	0.0006		7,560	32,228	3,741,998
18	40,001	0	758,672	1,177,524	0	0	0	0					1,936,196
19													
20		School Bus VMT	66,685,496										
21		% Diesel	81%										

### Federal VMT Spread

The *Federal VMT Spread* table uses the share of VMT for school buses and transit buses (*Bus VMT* tab) by weight classes to spread the federal bus VMT across vehicle weight classes. Similarly, the State and Local Government (SLG) VMT are used to spread the federal heavy vehicle VMT across weight classes. This table essentially creates the shares or weights for each weight class, which are then applied to the federal VMT input from the Federal table.

All of the calculations on this tab are linked to other tabs that help develop the *Base VMT* tab. The user may check that the shares are properly calculated and applied to the federal VMT such that the total federal VMT is still equal to the VMT on the *Federal VMT* tab.

### Federal Summary VMT

The *Federal Summary VMT* table sums the federal VMT by weight class from the *Federal* table and the *Federal VMT Spread* table.

Federal VMT for basic vehicles is the sum of the basic VMT from the Federal table and the federal bus VMT from the Federal VMT Spread table. Federal VMT for vehicles 10,001 pounds and above are the federal bus and truck VMT from the Federal VMT Spread table. Federal Gas VMT is derived by applying the percent gasoline from the SLG vehicles to the Federal VMT; Federal Diesel VMT is total Federal VMT less Federal Gas VMT.

Figure 36. Federal

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Federal Vehicle VMT													
2														
3	Instructions:													
4	Fill in cells highlighted this color (yellow) with the values from the tables.													
5	This worksheet calculates the share of federal vehicle US Post Service versus other Civilian agencies and applies those shares to the total number of federal motor vehicles in Oregon.													
6	Shares some input data with VMT by FC tab in Main Input Workbook.													
7														
8	Sources:													
9	2012 FHWA Highway Statistics, Table MV - 7, Publicly Owned Vehicles 2012. Accessed September 7, 2014 <a href="http://www.fhwa.dot.gov/policyinformation/statistics/2012/mv7.cfm">http://www.fhwa.dot.gov/policyinformation/statistics/2012/mv7.cfm</a>													
10	2013 Federal Fleet Report. US General Services Administration (GSA). Accessed September 7, 2014 <a href="http://www.gsa.gov/portal/category/102859">http://www.gsa.gov/portal/category/102859</a>													
11														
12	2012 FHWA Highway Statistics													
13	Table MV - 7, Publicly Owned Vehicles 2012, Federal - Motor Vehicles (1)													
14	State	Automobiles	Buses	Trucks & Truck Tractors	Total									
15	Oregon	2,612	43	6,315	8,970									
16														
17	2013 Federal Fleet Report													
18	Table 2-6, Passenger Vehicles*													
19	Department or Agency	Low-Speed	Sub-Compact	Compact	Midsize	Large	Limousines	Light SUVs	Medium SUVs	Light Pass Vans	Medium Pass Vans	Total		
20	Total Civilian Agencies	588	5,343	21,005	24,222	5,281	110	58,887	8,292	17,820	5,111	150,759		
21	U.S. Postal Service Agencies	13	115	4,109	4,725	143	0	1,072	0	709	2	8,888		
22														
23	Table 2-6, Trucks* and Other Vehicles													
24	Department or Agency	Light Duty 4x2	Light Duty 4x4	Medium Duty	Heavy Duty	Ambulances	Buses	Total						
25	Total Civilian Agencies	15,987	33,556	31,465	12,578	407	2,808	96,798						
26	U.S. Postal Service Agencies	185,947	1,774	7,191	4,997	1	9	199,919						
27														
28	Table 4-2, Average Miles Per Vehicle													
29	Department or Agency	Low-Speed	Sedans	Pass Vans	SUVs	Pass Subtotal	Light Trucks	Medium Trucks	Heavy Trucks	Truck Subtotal	Ambulances	Buses	Other Subtotal	Total
30	Total Civilian Agencies	1,982	10,562	9,494	9,031	10,075	8,688	7,182	4,900	7,689	11,323	10,818	10,883	5,178
31	Total U.S. Postal Service	0	7,751	6,071	6,126	7,409	5,485	5,602	22,580	5,017	3,028	2,735	2,784	5,980

Figure 37. Federal VMT Spread

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
70	Federal VMT Spread Table													
71	Spread Federal VMT across Weight Classes using the Distribution of Bus and SLG VMT													
72	Weight Class	Gas School Buses	Diesel School Buses	Diesel Transit Buses	Bus Total	Bus Percent (Bus Weight)	Spread Federal Buses	Gas SLG	Diesel & Other SLG	SLG Totals	SLG Medium Percent	SLG Heavy Percent	Spread Federal Trucks	SLG Gas Percent
73	1	0	0	0	0	0.00%	0	430,599,000	183,248,000	613,847,000	24.21%	55.97%	0	70.15%
74	10,001	32,690	139,364	8,185,945	8,357,999	8.69%	10,215	444,000	480,000	924,000	24.21%	55.97%	308,112	48.05%
75	12,001	719,183	3,065,990	3,785,173	3,933	3.93%	4,626	372,000	384,000	756,000	19.81%	55.97%	252,091	49.21%
76	14,001	52,304	222,982	0	275,286	0.29%	336	528,000	1,808,000	2,136,000	5.32%	55.97%	712,258	24.72%
77	16,001	39,228	167,236	0	206,464	0.21%	252	96,000	360,000	456,000	1.16%	55.97%	244,598	21.05%
78	18,001	45,766	195,108	0	240,874	0.25%	294	48,000	552,000	600,000	0.76%	55.97%	321,839	8.00%
79	20,001	457,662	1,951,084	0	2,408,746	2.50%	2,944	24,000	408,000	432,000	1.11%	55.97%	231,724	5.56%
80	22,001	640,726	2,731,519	0	3,372,245	3.51%	4,122	60,000	96,000	156,000	0.39%	55.97%	83,678	38.46%
81	24,001	2,902,884	12,375,451	777,448	16,055,783	16.69%	19,624	120,000	756,000	876,000	13.18%	55.97%	469,886	13.70%
82	26,001	1,379,523	6,881,127	21,397,423	28,658,073	29.79%	35,026	33,000	110,000	143,000	2.15%	55.97%	75,106	23.88%
83	28,001	1,281,453	5,463,037	7,249,577	13,994,068	14.55%	17,104	55,000	946,000	1,001,000	15.06%	55.97%	536,935	5.49%
84	30,001	1,876,414	7,999,447	924,862	10,800,722	11.23%	13,201	22,000	539,000	561,000	8.44%	55.97%	300,919	3.92%
85	32,001	523,042	2,229,811	0	2,752,853	2.86%	3,365	11,000	462,000	473,000	7.12%	55.97%	253,716	2.33%
86	34,001	987,242	4,208,769	0	5,196,011	5.40%	6,351	11,000	319,000	330,000	4.97%	55.97%	177,011	3.33%
87	36,001	13,076	55,746	0	68,822	0.07%	84	22,000	715,000	737,000	11.09%	55.97%	395,326	2.99%
88	38,001	6,538	27,872	0	34,410	0.04%	42	22,000	187,000	209,000	3.15%	55.97%	112,107	10.53%
89	40,001	0	0	0	0	0.00%	0	11,000	33,000	44,000	0.66%	55.97%	23,602	25.00%
90	42,001	0	0	0	0	0.00%	0	33,000	56,000	89,000	1.32%	55.97%	47,203	37.50%
91	44,001	0	0	0	0	0.00%	0	0	33,000	33,000	0.50%	55.97%	17,701	0.00%
92	46,001	0	0	0	0	0.00%	0	11,000	77,000	88,000	1.32%	55.97%	47,203	12.50%
93	48,001	0	0	0	0	0.00%	0	0	66,000	66,000	0.99%	55.97%	35,402	0.00%
94	50,001	0	0	0	0	0.00%	0	0	22,000	22,000	0.33%	55.97%	11,801	0.00%
95	52,001	0	0	0	0	0.00%	0	0	44,000	44,000	0.66%	55.97%	23,602	0.00%
96	54,001	0	0	0	0	0.00%	0	0	55,000	55,000	0.83%	55.97%	29,502	0.00%
97	56,001	0	0	0	0	0.00%	0	0	22,000	22,000	0.33%	55.97%	11,801	0.00%
98	58,001	0	0	0	0	0.00%	0	0	11,000	11,000	0.17%	55.97%	5,900	0.00%
99	60,001	0	0	0	0	0.00%	0	0	0	0	0.00%	0	0.00%	
100	62,001	0	0	0	0	0.00%	0	0	11,000	11,000	0.17%	55.97%	5,900	0.00%
101	64,001	0	0	0	0	0.00%	0	0	22,000	22,000	0.33%	55.97%	11,801	0.00%

Figure 38. Federal Summary VMT

	A	B	C	D
126	Federal VMT Summary for Gas and Diesel Vehicles			
127	Weight Class	Federal VMT	Federal Gas	Federal Diesel
128	1	51,879,874	36,392,492	15,487,382
129	10,001	318,327	152,962	165,365
130	12,001	256,718	126,321	130,396
131	14,001	712,595	176,147	536,448
132	16,001	244,850	51,547	193,303
133	18,001	322,133	25,771	296,363
134	20,001	234,868	13,037	221,831
135	22,001	87,800	33,769	54,031
136	24,001	489,508	67,056	422,452
137	26,001	111,731	25,784	85,947
138	28,001	554,038	30,442	523,597
139	30,001	314,120	12,318	301,802
140	32,001	257,081	5,979	251,102
141	34,001	183,362	6,112	177,250
142	36,001	395,410	11,803	383,606
143	38,001	112,149	11,805	100,344
144	40,001	23,602	5,900	17,701
145	42,001	47,203	17,701	29,502
146	44,001	17,701	0	17,701
147	46,001	47,203	5,900	41,303
148	48,001	35,402	0	35,402
149	50,001	11,801	0	11,801
150	52,001	23,602	0	23,602
151	54,001	29,502	0	29,502
152	56,001	11,801	0	11,801
153	58,001	5,900	0	5,900
154	60,001	0	0	0
155	62,001	5,900	0	5,900
156	64,001	11,801	0	11,801
157	66,001	0	0	0
158	68,001	5,900	0	5,900
159	70,001	0	0	0
160	72,001	0	0	0
161	74,001	5,900	0	5,900
162	76,001	11,801	5,900	5,900
163	78,001	64,904	5,900	59,004
164	80,001	0	0	0
165	82,001	0	0	0
166	84,001	0	0	0
167	86,001	0	0	0
168	88,001	0	0	0
169	90,001	0	0	0
170	92,001	0	0	0
171	94,001	0	0	0
172	96,001	0	0	0
173	98,001	0	0	0
174	100,001	0	0	0

**BASE VMT**

The *Base VMT* tab contains the base-year VMT by weight class and vehicle tax class. The base-year VMT are used in the model to calculate the model-year VMT. The base-year VMT are used to allocate costs and attribute revenues by vehicle tax and weight class. The *Base VMT* tab is built using the *General*, *DMV VMT*, *MCTD VMT*, *Federal VMT*, *Bus VMT*, and *VMT Growth* tabs.

The *Base VMT* tab adjusts the basic and medium-heavy VMT so that the total for these two weight groupings equals their corresponding VMT forecast from the ODOT Economic and Revenue Forecast (for the base year). The VMT estimates for the base year from the ODOT Transportation and Revenue forecast are pasted into the yellow-shaded

cells to the right of the VMT table on the *VMT Growth* tab (see [Figure 44 on page D25](#)). The VMT estimates for the base year are the control totals for the basic vehicle and medium-heavy vehicle classes. The *Base VMT* and *DMV VMT* tabs both reference these control totals and use the medium vehicle control total to calculate the scaling factor used to adjust the medium-heavy VMT for each vehicle tax class. A more detailed discussion of the *VMT Growth* tab is provided later on in this section.

The VMT for the tax classes calculated separately (transit, school bus, etc.) are subtracted from the light-vehicle control total to determine the Private Passenger basic VMT. The medium-heavy vehicle VMT are scaled such that the total medium-heavy vehicle VMT equals the control total. The medium-heavy

control total adjustment factor is applied to the VMT for medium-heavy vehicle classes (vehicles between 10,001 and 26,000 pounds).

The WMT VMT reflect the WMT VMT reported in the WMT Collection Reports. The WMT VMT are adjusted to include an assumed WMT evasion factor. The WMT evasion factor<sup>9</sup> adjusts the WMT VMT to account for the additional VMT not reported for WMT payments. The WMT evasion factor is a user-specified assumption located on the *General* tab in the Control table.

In the 2015 HCAS, all inputs that build the *Base VMT* tab are linked to it and the tab automatically updates. Similarly, a number of other tabs reference the *Base VMT* tab and also update automatically (e.g., development of growth factors on the *VMT Growth* tab for weight classes 26,001 to 104,001 pounds).

**Figure 39. Base VMT**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Weight Class	Private Passenger	Gas Commercial 10-26	Diesel & Other Commercial 10-26	Gas Tow Trucks	Diesel & Other Tow Trucks	RUAUF Vehicles	Flat Fee Vehicles Log	Flat Fee Vehicles S&G	Flat Fee Vehicles Chip	WMT Vehicles 26-80 Any Axle	WMT Vehicles 80+ 5 Axle	WMT Vehicles 80+ 6 Axle	WMT Vehicles 80+ 7 Axle	WMT Vehicles 80+ 8 Axle	WMT Vehicles 80+ 9+ Axle	Gas Farm
2	WC	Cars	GasComm	DieselComm	GasTow	DieselTow	RUAUF	FlatFeeLog	FlatFeeSG	FlatFeeChip	WMTA	WMTB5	WMTB6	WMTB7	WMTB8	WMTB9	GasFarm
3	1	30,421,163,637	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	10,001	18,225,160	42,402,635	48,822,431	420,000	1,110,000	0	0	0	0	0	0	0	0	0	0	1,374,000
5	12,001	12,079,652	17,797,227	35,662,992	345,000	3,800,000	0	0	0	0	0	0	0	0	0	0	669,000
6	14,001	33,084,448	25,907,645	74,592,998	510,000	2,415,000	0	0	0	0	0	0	0	0	0	0	1,212,000
7	16,001	20,528,236	9,115,653	44,367,413	135,000	1,620,000	0	0	0	0	0	0	0	0	0	0	798,000
8	18,001	16,697,756	7,196,568	44,710,106	135,000	2,580,000	0	0	0	0	0	0	0	0	0	0	1,386,000
9	20,001	0	2,535,933	10,760,583	45,000	465,000	0	0	0	0	0	0	0	0	0	0	637,000
10	22,001	7,684,876	4,249,402	15,421,217	15,000	765,000	0	0	0	0	0	0	0	0	0	0	1,235,500
11	24,001	9,311,980	15,421,217	132,805,237	405,000	9,885,000	0	0	0	0	0	0	0	0	0	0	2,684,500
12	26,001	4,709,828	0	0	0	0	0	0	10,935	0	2,391,059	0	0	0	0	0	1,218,000
13	28,001	4,949,108	0	0	0	0	0	0	0	0	3,995,673	0	0	0	0	0	1,102,500
14	30,001	15,728,672	0	0	0	0	0	0	0	0	9,726,469	0	0	0	0	0	735,000
15	32,001	0	0	0	0	0	0	0	0	0	22,936,441	0	0	0	0	0	196,000
16	34,001	0	0	0	0	0	0	0	0	0	4,679,480	0	0	0	0	0	154,000
17	36,001	0	0	0	0	0	0	0	0	0	2,514,291	0	0	0	0	0	56,000
18	38,001	0	0	0	0	0	0	0	0	0	3,537,992	0	0	0	0	0	147,000
19	40,001	0	0	0	0	0	0	0	0	0	3,564,333	0	0	0	0	0	124,000
20	42,001	0	0	0	0	0	0	0	0	0	3,423,305	0	0	0	0	0	400,000
21	44,001	0	0	0	0	0	0	0	300	0	32,983,660	0	0	0	0	0	520,000
22	46,001	0	0	0	0	0	0	0	105,713	0	12,898,123	0	0	0	0	0	324,000
23	48,001	0	0	0	0	0	0	0	0	0	14,930,438	0	0	0	0	0	288,000
24	50,001	0	0	0	0	0	0	0	14,124	0	14,215,658	0	0	0	0	0	31,500
25	52,001	0	0	0	0	0	0	0	0	0	25,372,851	0	0	0	0	0	67,500
26	54,001	0	0	0	0	0	0	0	42,344	0	24,570,818	0	0	0	0	0	27,000
27	56,001	0	0	0	0	0	0	0	73,174	0	8,615,805	0	0	0	0	0	0
28	58,001	0	0	0	0	0	0	0	0	0	8,154,367	0	0	0	0	0	18,000
29	60,001	0	0	0	0	0	0	0	0	0	1,505,577	0	0	0	0	0	0
30	62,001	0	0	0	0	0	0	0	0	0	2,531,394	0	0	0	0	0	4,500
31	64,001	0	0	0	0	0	0	0	12,960	0	10,622,171	0	0	0	0	0	13,500
32	66,001	0	0	0	0	0	0	0	0	0	2,624,002	0	0	0	0	0	4,500
33	68,001	0	0	0	0	0	0	0	0	0	5,319,462	0	0	0	0	0	0
34	70,001	0	0	0	0	0	0	0	0	0	3,222,945	0	0	0	0	0	10,000
35	72,001	0	0	0	0	0	0	0	0	0	2,297,238	0	0	0	0	0	0
36	74,001	0	0	0	0	0	0	0	0	0	5,445,831	0	0	0	0	0	10,000
37	76,001	0	0	0	0	0	0	0	0	0	989,228	0	0	0	0	0	0
38	78,001	0	0	0	0	0	0	31,303,827	185,984	0	1,026,162,913	0	0	0	0	0	150,000
39	80,001	0	0	0	0	0	0	2,638,939	0	0	0	7,326,703	241,909	252,735	25,628	12,784	6,000
40	82,001	0	0	0	0	0	0	0	0	0	0	8,853,886	851,597	91,222	57,051	8,431	0

<sup>9</sup>WMT evasion factor is calculated as one divided by one minus the WMT evasion percent (1/(1-WMT Evasion)).

**GENERAL**

**Control**

Enter the biennium study period and the bond factor in the *Control* table.

To update the study biennium, enter the first year of the biennium in the yellow-shaded cell next to the “Study biennium” cell. The biennium start year should be the calendar year for the first year of the biennium.

Enter the bond factor in the yellow-shaded cell next to the bond factor label. The bond factor can be calculated by using Excel’s PMT function. The bond factor should be the share of payments on bond expenditures in this biennium paid in this biennium.

The Excel PMT function calculates the bond loan payment based on the assumptions of constant repayment periods and a constant interest rate. In the 2015 HCAS and previous studies, the bond factor has been calculated using a repayment period of 20 years and an interest rate of 5 percent. The bond factor is used in the model to calculate the portion of bond expenditures allocated to the current study.

Assumptions located in the bottom of the portion of the *Control* table include user-specified assumptions for the gas, diesel, and WMT avoidance or evasion rates; the percent of basic VMT by diesel-fueled vehicles; the RUAF registration revenue allocation; empty log truck miles and weight; and the percentage of taxed gallons that are diesel.

The gas tax avoidance rate and the diesel tax avoidance/evasion rate are both expressed as the percent of total taxable VMT that avoids the

gas tax by purchasing fuel out-of-state. The avoidance/evasion rates are applied to their respective gas and diesel VMT to calculate gas and diesel tax revenues. Change these assumptions by entering a percentage in the yellow-shaded evasion cells.

Similarly, the WMT evasion rate is expressed as the percent of total WMT VMT that evades the WMT. The WMT evasion rate is applied to WMT vehicle class VMT to calculate WMT revenues. The WMT evasion rate is also used to adjust the WMT base VMT in the *Base VMT* tab because the base VMT data are calculated from the WMT tax collection reports. Change the WMT evasion rate by entering a percentage in the yellow-shaded “WMT Evasion” cell.

The percent of basic VMT by diesel-powered vehicles is used to split basic vehicle VMT into gasoline-powered VMT and diesel-powered VMT for the calculation of gasoline and diesel tax revenues. Change the assumption by entering a percentage in the yellow-shaded “Basic Diesel” cell.

RUAF vehicles are credited with a portion of the heavy vehicle registration revenues using the RUAF registration assumptions. The first RUAF registration assumption is the RUAF Registration Adjustment in dollars per mile. This assumption is the registration revenue dollars per RUAF mile credited to the RUAF vehicles class. The next three RUAF registration assumptions allocate the RUAF registration revenue across three RUAF vehicle weight groups by specifying the portion of RUAF vehicles, which register at

**Figure 40. Control**

	A	B	C	D	E
1					
2	<b>Control</b>				
3	<b>Study biennium</b>	2015	to 2017		
4	Base year	2013			
5	Model year	2016			
6					
7	<b>Bond Factor</b>	0.160485	(biennial repayment amount per dollar of bonded expenditure; assumes 20-yr repayment)		
8					
9	<b>Gas Tax Avoidance</b>	3.53%	(percent of total that is avoided)		
10	<b>Diesel Tax Evasion &amp; Avoidance</b>	4.53%	(percent of total that is avoided or evaded)		
11	<b>WMT Evasion</b>	5.00%	(percent of total that is evaded)		
12	<b>Basic Diesel</b>	5.00%	(percent of basic VMT by diesel-powered vehicles)		
13	<b>RUAF Registration Adjustment</b>	0.0450	(dollars per mile)		
14	<b>RUAF Reg. from 78,001</b>	14%	(percent of total)		
15	<b>RUAF Reg. from 96,001</b>	15%	(percent of total)		
16	<b>RUAF Reg. from 104,001</b>	71%	(percent of total)		
17	<b>Log truck miles empty</b>	50%	(percent of VMT empty)		
18	<b>Empty log truck declared weight</b>	42,001	(declared weight category, use valid 2,000 lb weight class)		
19	<b>Taxed diesel</b>	9.47%	(percent of taxed gallons that are diesel)		

three different registration weight classes. RUAF Reg. from 78,001, RUAF Reg. from 96,001, and RUAF Reg. from 104,001 must be entered as percentages in the yellow-shaded cells. The total of these three assumptions must equal 100 percent.

Two assumptions are used to adjust the log truck VMT for the “as if” WMT revenue calculations. The “Log truck miles empty” assumption specifies the percent of log truck VMT without a load (empty), and the “Empty log truck declared weight” is the weight class the empty log truck VMT are assigned (enter a valid HCAS vehicle weight class). Log truck VMT in the flat fee reports should be reported using the loaded weight. Since log haulers are allowed to use a lower declared weight when their trailer is empty and stowed above the tractor unit, the log truck VMT must be adjusted to take into account the empty VMT at the lower weight class for calculation of the as-if WMT tax revenues.

### Gas and Diesel

The *Gas and Diesel* table uses VMT from the *Base VMT* tab and rates from the *VMT Growth* tab to determine VMT in the model year for gas and diesel vehicles. The VMT and user-specified assumptions are used to determine the implied gallons and implied MPG for basic and non-basic vehicle classes.

The middle portion of the table is the average annual gas and diesel tax revenues. Gas tax revenues and diesel tax revenues from the *Revenue Forecast* tab are added and divided by two to calculate the average annual revenue (“Total” column). This is then allocated between basic and non-basic and divided by the gas/diesel tax rate per gallon to calculate the total implied gallons.

Once the base VMT, VMT growth rates, and revenue totals have been updated, adjust the yellow-shaded assumptions until the green-highlighted implied MPG are reasonable for their corresponding vehicle class. Reasonable MPG

is about 20 for basic vehicles and about 10 for non-basic vehicles, with the gas MPG higher than the diesel MPG.

Using VMT by weight class from the *Base VMT* tab and MPG assumptions by weight class from the *MPG* tab, the “Percent of taxed gallons that are basic” is equal to the taxed gallons for vehicles under 10,000 pounds divided by the total taxed gallons.

The yellow-shaded assumptions are percent of basic gallons that are diesel and percent of RV gallons that are diesel. The user should adjust these assumptions using the values specified in the previous study as starting points.

- The “Percent of basic gallons that are diesel” is entered as a percent. A reasonable range for this assumption is between 5 and 8 percent.<sup>10</sup>
- The “Percent of RV gallons that are diesel” is entered as a percent. A reasonable range for this assumption is between 30 and 60 percent.<sup>10</sup>

**Figure 41. Gas and Diesel**

	A	B	C	D	E
21					
22	<b>Gas and Diesel</b>				
23	<b>VMT from Model</b>	<b>Taxed Gas</b>	<b>Taxed Diesel</b>	<b>Taxed Unknown</b>	<b>Total</b>
24	Basic	474,169,108	7,517,711	32,251,303,582	32,732,990,401
25	Non-Basic	185,111,760	585,973,009	148,985,879	920,070,648
26	All	659,280,868	593,490,720	32,400,289,461	33,653,061,049
27					
28	Percent of basic gallons that are diesel	5.00%	Change these until the green cells look reasonable		
29	Percent of RV gallons that are diesel	40.00%			
30	Percent of taxed gallons that are basic	94.06%			
31					
32	<b>Implied Gallons</b>	<b>Gas</b>	<b>Diesel</b>	<b>Total</b>	
33	Basic	1,565,549,129	82,397,323	1,647,946,452	
34	Non-Basic	20,623,271	83,526,157	104,149,428	
35	All	1,586,172,400	165,923,480	1,752,095,880	
36					
37	<b>Implied MPG</b>	<b>Gas</b>	<b>Diesel</b>	<b>Total</b>	
38	Basic			19.86	
39	Non-Basic	13.31	7.73		
40	All				

### Bridge Splits

The *Bridge Splits* table (see [Figure 42](#) on the following page) contains the split of the bridge costs for the incremental allocation of bridge project expenditures. The available bridge types and the bridge reclassification work types are listed on the *Codes* tab.

Work types 60 through 65 are designated bridge reclassification codes for splitting the bridge project expenditures. Expenditures entered for bridge projects work types (work types 13, 14, 15, 16, 19, or 68) in the *Project Costs* tab are reclassified using their bridge

<sup>10</sup>The ranges for these user-specified rates are only guidelines; the objective should be reasonable MPG estimates.

type and work type into work types 60 through 65. This bridge splits are used by the model for the incremental bridge cost allocation approach used in the study. The user may adjust the share for each bridge type and work type, such that the sum of the shares by bridge type equals one.

**Studded Tires**

The *Studded Tires* table contains the state and local studded tire-related expenditures. A 2014 review of studded tires in Oregon by ODOT provided projected studded tire expenditures for state roads.<sup>11</sup> The 2015 HCAS uses the same distribution by work type as the 2013 HCAS.

Local studded tire costs are estimated from the state studded tire costs using the share of basic VMT on local roads compared to basic VMT on state roads. The “Speed-Adjusted Local to

State Basic VMT on Urban Principal Arterials and Above” is applied to the state studded tire expenditures to calculate the local expenditures for each studded tire-related work type. The speed-adjusted local to state basic VMT should not change much between studies.

**VMT GROWTH**

The *VMT Growth* tab has VMT controls (base-year and model-year VMT) and VMT growth by vehicle class (light, medium, heavy) and then detailed growth rates and growth factors by weight class.

The VMT growth rates are calculated from the change in VMT from the base year to the model year in the ODOT Economic and Revenue Forecast. To update the growth rates, paste the

ODOT Economic and Revenue Forecast VMT by vehicle class (light, medium, heavy) into the yellow-shaded cells in the table displayed in [Figure 44](#) so that the base year and model year match the Base Year and Model Year columns. The compound VMT growth rates are automatically calculated for light, medium, and heavy vehicle classes.

VMT growth rates by weight class for the basic and medium vehicle classes as well as weight classes over 106,001 pounds (heavy) are set equal to their calculated compound vehicle class growth rates.

For weight classes between 26,001 and 104,001, growth factors are developed such that variation across heavy weight classes exists. The heavy vehicle growth rates for these weight classes are automatically adjusted such that the total heavy vehicle VMT growth rate matches the target VMT growth rate, but variation still exists across the weight classes within the heavy vehicles. Using the distribution of VMT from 2011, base-year VMT and model-year VMT, growth factors are automatically developed for weight classes between 26,001 to 104,001 pounds (see [Figure 45](#)).

Small modifications in the VMT growth rates for the weight classes from 78,001 and 104,001 pounds will have the greatest impact on the total heavy vehicle group VMT growth rate since a majority of the heavy vehicle VMT are in these two weight classes.

The VMT growth rates by weight class are applied to the base-year VMT data to calculate the model-year VMT.

**Figure 42. Bridge Splits**

	A	B	C
42			
43	Bridge Splits		
44	Bridge Type	Work Type	Share
45	0	60	0.6849
46	0	61	0.2520
47	0	62	0.0000
48	0	63	0.0000
49	0	64	0.0631
50	1	60	0.6666
51	1	61	0.2999
52	1	62	0.0000
53	1	63	0.0000
54	1	64	0.0335
55	2	60	0.6849
56	2	61	0.2520
57	2	62	0.0000
58	2	63	0.0000
59	2	64	0.0631
60	3	60	0.7221
61	3	61	0.1697
62	3	62	0.0000
63	3	63	0.0514
64	3	64	0.0568
65	4	60	0.8713
66	4	61	0.1029
67	4	62	0.0000

**Figure 43. Studded Tires**

	A	B	C	D	E
71					
72	Studded Tires				
73	Funding	Work Type	Facility Class	Dollars	Distributon by Work Type
74	state	1	0	407,453	5%
75	state	11	0	6,790,885	79%
76	state	26	0	1,372,441	16%
77	local-state	101	-2	44,820	
78	local-state	111	-2	746,997	
79	local-state	126	-2	150,968	
80					
81	Study biennium projected studded tire expenditures by road type:				
82				state	8,570,779
83				local-state	942,786
84	Speed-Adjusted Local to State Basic VMT on Urban Principal Arterials and Above				0.11

**Figure 44. Oregon Transportation Economic and Revenue Forecast**

	E	F	G	H	I
1	ODOT Forecast	Base 2013	Model 2016	Forecast Growth	Weighted Average
2	Light	31,058,764,544	32,927,262,617	1.97%	
3	Medium	780,033,522	843,275,225	2.63%	
4	Heavy	1,770,824,870	1,951,715,914	3.30%	3.30%

<sup>11</sup> The projected expenditures for the study biennium include half of the projected expenditures for 2015 and 2017 and the all of the projected expenditures for 2016.

**Figure 45. Development of VMT Growth Rates for Heavy Vehicles (26,001 to 104,001 pounds)**

	E	F	G	H	I	J	K	L
10	Weight Class	Prior 2011	Scaled 2013	Shift	Shifted Again	Re-scaled	Grown 2016	Growth Factor
11	26,001	67,264,185	33,522,881	0.4984	17,160,636	16,692,577	18,397,735	0.5343
12	28,001	40,757,424	35,240,621	0.8646	31,297,883	30,444,228	33,554,128	0.9270
13	30,001	49,750,277	43,477,080	0.8739	39,026,520	37,962,065	41,839,917	0.9369
14	32,001	30,865,543	30,939,554	1.0024	31,855,818	30,986,944	34,152,283	1.0747
15	34,001	15,994,698	13,862,466	0.8667	12,340,693	12,004,098	13,230,326	0.9292
16	36,001	5,111,521	9,085,565	1.7775	16,587,782	16,135,347	17,783,585	1.9056
17	38,001	5,367,612	9,641,691	1.7963	17,789,344	17,304,136	19,071,766	1.9258
18	40,001	3,781,144	6,067,708	1.6047	10,001,400	9,728,610	10,722,394	1.7204
19	42,001	4,254,383	4,974,107	1.1692	5,973,491	5,810,563	6,404,116	1.2535
20	44,001	33,991,317	35,151,970	1.0341	37,339,280	36,320,845	40,031,045	1.1087
21	46,001	14,607,725	16,086,906	1.1013	18,196,885	17,700,562	19,508,687	1.1806
22	48,001	18,561,539	17,611,158	0.9488	17,163,127	16,695,000	18,400,406	1.0172
23	50,001	14,390,433	14,970,278	1.0403	15,996,333	15,560,030	17,149,499	1.1153
24	52,001	23,526,887	26,659,430	1.1331	31,029,291	30,182,961	33,266,173	1.2148
25	54,001	24,136,216	25,701,240	1.0648	28,110,824	27,344,096	30,137,315	1.1416
26	56,001	8,261,171	8,781,023	1.0629	9,587,012	9,325,524	10,278,133	1.1396
27	58,001	8,024,277	8,470,851	1.0557	9,185,077	8,934,552	9,847,223	1.1318
28	60,001	1,452,615	1,535,875	1.0573	1,668,000	1,622,505	1,788,245	1.1335
29	62,001	2,320,196	2,623,153	1.1306	3,046,190	2,963,105	3,265,788	1.2121
30	64,001	13,133,508	10,733,658	0.8173	9,010,509	8,764,746	9,660,071	0.8762
31	66,001	2,971,272	2,617,921	0.8811	2,369,220	2,304,599	2,540,015	0.9446
32	68,001	7,495,703	5,359,427	0.7150	3,936,035	3,828,678	4,219,781	0.7685
33	70,001	2,916,124	3,196,164	1.0960	3,598,211	3,600,070	3,857,604	1.1750
34	72,001	2,146,539	2,299,795	1.0714	2,530,894	2,461,863	2,713,344	1.1486
35	74,001	4,598,407	5,433,776	1.1817	6,595,242	6,415,355	7,070,688	1.2669
36	76,001	1,229,419	1,231,749	1.0019	1,267,590	1,233,016	1,358,970	1.0741
37	78,001	1,033,542,841	1,037,186,639	1.0035	1,069,103,956	1,039,943,952	1,146,174,981	1.0759
38	80,001	9,108,557	10,308,797	1.1318	11,983,979	11,657,114	12,847,896	1.2134
39	82,001	12,047,339	9,724,159	0.8072	8,062,088	7,842,193	8,643,279	0.8654
40	84,001	15,262,630	14,844,898	0.9726	14,830,632	14,426,124	15,899,763	1.0427
41	86,001	26,438,586	29,360,320	1.1105	33,490,216	32,576,764	35,904,504	1.1906
42	88,001	38,582,262	34,095,266	0.8837	30,948,178	30,104,061	33,179,212	0.9474
43	90,001	6,788,535	18,115,989	2.6686	49,657,241	48,302,831	53,237,000	2.8610
44	92,001	3,826,269	4,068,459	1.0633	4,443,437	4,322,242	4,763,762	1.1399

**Figure 46. VMT by FC Ownership**

	A	B	C	D	E	F	G	H	I
1	VMT by Functional Class								
2	Functional System				Ownership				
3	1	2	3	4	5	6	7	8	9
4	1	4,183,325,520	0	0	0	0	0	0	0
5	2	4,324,050,654	144,887,049	0	0	0	0	0	0
6	6	1,630,643,912	450,284,246	0	0	0	939,451	0	0
7	7	392,779,149	1,688,906,263	43,508,723	0	0	23,670,460	3,327,088	0
8	8								
9	9								
10	11	4,505,526,655	0	0	0	0	0	0	0
11	12	1,293,855,473	26,982,369	11,592,590	0	0	0	0	0
12	14	3,173,620,855	174,766,873	1,246,831,630	3,521,594	11,807,594	0	0	0
13	16	167,616,018	1,259,711,792	2,196,106,716	0	0	0	0	0
14	17	585,960	555,856,369	1,639,566,523	3,784,261	0	0	0	0
15	19								

**Figure 47. Oregon VMT from Highway Statistics: Rural and Urban**

	A	B	C	D	E	F	G	H
18	Oregon VMT from Highway Statistics							
19	Rural							
20	State	Interstate	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local	Total
21	Oregon	4,103	4,387	2,052	2,025	508	1,456	14,531
22	Oregon VMT from Highway Statistics							
23	Urban							
24	Interstate	Other Freeways & Expressways	Other Principal Arterial	Minor Arterial	Collector	Local	Total	Total
25	4,455	1,320	4,767	3,722	2,277	2,099	18,642	33,173

**VMT BY FC**

The *VMT by FC* tab calculates VMT by functional system and ownership, which is used in the model with the *Base VMT* and *VMT Growth* input tabs.

Two data sources are used to update the input on this tab: Oregon's Highway Performance Monitoring System (HPMS) submission data and data from the annual Federal Highway Administration (FHWA) *Highway Statistics* report.

The Oregon HPMS submission data corresponding to the base year are pre-processed outside of the HCAS model. The summary table of VMT by functional system and ownership is pasted into the yellow-shaded cells in the table at the top of the *VMT by FC* tab (see [Figure 46](#)).

The second data source needed to update the *VMT by FC* tab is the Oregon information from the FHWA *Highway Statistics* Report Table VM-2. Paste the Oregon row from Table VM-2 into the yellow-shaded cells in the middle row of the tab (see [Figure 47](#)).

The input data are combined into a single table of VMT by functional system and ownership at the bottom right of the tab. This table is then used to create the column of VMT by facility class located at the bottom left of the tab.

**NON-PROJECT COSTS**

The *Non-Project Costs* tab (see [Figure 48](#) on the following page) contains the administrative and non-project-related costs by funding source. The non-project costs are allocated to the vehicle weight classes in the model cost allocation calculations. The *Non-Project Costs* tab includes the DMV and Motor Carrier collection costs, ROW costs, and PE costs. Non-project maintenance costs are broken out by their specific maintenance work category. The data for the *Non-Project Costs* tab are based on ODOT's proposed budget. ODOT staff complete a worksheet with the same format as the tables of the *Non-Project Costs* tab. When pasting the data into the tables, it is important that the row and column headings match exactly because the non-project cost entries at the bottom of the tab are referenced by work type to the input data.

Figure 48. Non-Project Costs

	A	B	C	D	E	F	G	H
	Work Type	State Funded	Federal Funded	Bond Funded	Other Funded	OTIA Funded	JTA Funded	Category
1								
2	2	7,111,207	25,115,052	0	7,202,369	0	2,575,754	Project Right of Way and Utilities
3	1	19,241,968	67,957,944	0	19,488,639	475,167	500,021	Other Project-Related (PE)
4	20	1,500,000	0	0	0	0	0	Safety Rest Area Improvements & Access Mgmt
5	22	13,255,613	7,700,000	0	0	0	0	Traffic Operations Centers, ITS, Incident Response & Traffic Signal Services
6	50	24,293,505	0	0	0	0	0	Local Government Support - Regional and Central (Locals may participate)
7	50	174,127,562	0	0	0	0	0	Special Programs (Central, Regional, Tech Services Construction support)
8	55	80,107,319	5,940,865	0	0	0	0	Motor Carrier (All) & Central Services Collection Costs-Trucks Only
9	58	3,846,370	0	0	0	0	0	Fuel Tax Collection Costs (includes CS)
10	56	39,849,597	0	0	0	0	0	Reg Fee Collection Costs-Basic Only (includes CS)
11	58	3,355,142	0	0	0	0	0	Reg Fee Collection Costs-Non-Basic Only (includes CS)
12	56	54,007,529	0	0	0	0	0	Title Collection Costs - Light (includes CS)
13	57	1,242,087	0	0	0	0	0	Title Collection Costs - Heavy (includes CS)
14	50	115,834,483	278,321	0	0	0	0	Central Services budget: ARB Hwy Division portion of CS assessment
15	43	5,806,754	55,823,130	0	0	0	0	Transit: STP Funds
16	42	1,400,000	22,551,911	0	0	0	0	Rail: Grade Crossing Protection Fund (from Highway Fund)
17	21	4,391,951	18,659,948	0	0	0	0	T. Safety: Highway Funded Positions & STP
18	50	98,339,786	178,980	33,976,920	0	0	0	Transportation Program Development
19	40	11,922,463	0	0	0	0	0	OPS/SpPgms/Permits
20	40	16,061,008	0	0	0	0	0	State Radio System
21	26	122,417,001	15,000,000	0	0	0	0	Surface/Shoulder/Contract
22	28	19,641,056	0	0	0	0	0	Drainage
23	30	60,505,518	0	0	0	0	0	Roadside & Vegetation
24	32	62,084,533	4,757,000	0	0	0	0	Traffic Services & ITS
25	29	18,576,955	0	0	0	0	0	Bridge (Structures)
26	34	122,085,856	0	0	0	0	0	Snow & Ice/Extraordinary
27	40	19,719,533	0	0	0	0	0	Risk Mgmt
28								
29		167,924,803	577,438,850	0	170,064,561	10,335,158	213,025,277	Project Construction
30		287,093,064	0	0	0	56,146,426	160,182,166	Counties
31		182,987,244	0	0	0	41,099,933	106,788,110	Cities

Figure 49. Local Costs

	A	B	C	D	E	F
	ITEM	AMOUNT				TOTAL RECEIPTS
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
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LOCAL COSTS

The *Local Costs* tab contains the local agency expenditures by project work type, facility class, and bridge type. The Local Roads and Streets Survey (LRSS) receipts and disbursements data are used to update the *Local Costs* tab. The LRSS data should be pasted in the yellow-shaded cells on the *Local Costs* tab. Make sure that the LRSS data are pasted into the correct rows because the calculations refer to specific cells for the different expenditure types.

Once the LRSS data are pasted into the *Local Costs* tab, calculations are performed to remove the non-fungible local revenue sources from the expenditures and then sum the remaining expenditures by HCAS work type. The *Local Costs* tab calculations automatically update the local costs table at the bottom of the *Local Costs* tab.

Figure 50. Project Costs

	A	B	C	D	E	F
	Work Type	Functional Class	Bridge Type	Dollars	Key Number	
1						
2	federal	5	0	0	4,913,904	K09436
3	other	5	0	0	533,347	K09436
4	state	5	0	0	478,827	K09436
5	federal	11	0	0	47,500	K11017
6	other	11	0	0	1,159	K11017
7	state	11	0	0	452	K11017
8	state	5	0	0	60,038	K11196
9	other	5	0	0	16,056	K11196
10	state	41	0	0	168,856	K11196
11	state	41	0	0	146,342	K11196
12	other	41	0	0	45,157	K11196
13	other	41	0	0	39,136	K11196
14	federal	5	0	0	2,684,324	K11258
15	state	5	0	0	307,233	K11258
16	federal	44	0	0	2,477,837	K11258
17	state	44	0	0	283,600	K11258
18	federal	14	0	2	155,559	K12001
19	other	14	0	2	42,202	K12001
20	federal	15	0	3	120,714	K12692
21	state	15	0	3	13,816	K12692
22	federal	4	0	2	12,735,763	K12723
23	other	4	0	2	1,576,794	K12723
24	state	4	0	2	1,455,381	K12723
25	federal	15	0	2	1,107,458	K12723

PROJECT COSTS

The *Project Costs* tab contains the project costs for the biennium, which are allocated to vehicle classes in the cost allocation procedure in the model.

Project expenditures are broken out by their funding source, work type, and bridge type (if applicable). Only one functional system is assigned to the project, but the project may have up to four funding sources (federal, state, local, bond), three work types (see work type codes on the *Codes*

tab), and three bridge types, which correspond to the work types (bridge types are also listed on the *Codes* tab). Thus, a single project may be listed multiple times in the *Project Costs* tab, once for each possible funding source, work type, and bridge type combination. The user may change the *Project Costs* input data by pasting project expenditures into the rows. The model ignores entries in the Key Number column and stops reading data at the first empty row, so be sure eliminate spaces between entries.

**REVENUE FORECAST**

The ODOT Revenue Forecast (total revenue dollars) by revenue source for the study period should be pasted into the yellow-shaded cells on the *Revenue Forecast* tab. The ODOT Revenue Forecast is provided by the Financial and Economics Analysis Unit of the ODOT Financial Services Branch. Make sure the row and column headings in the tab correspond to the new data when pasting the new revenue

**Figure 51. Revenue Forecast**

	A	B
1	<b>Revenue Source</b>	<b>Gross</b>
2	Basic/Motorcycle/Moped Light Reg	314,161,649
3	Truck Normal Reg	33,550,449
4	Bus Normal Reg	738,168
5	Farm Reg	6,258,719
6	Charitable/Non-Profit Reg	285,138
7	Tow Reg	603,028
8	Heavy Fixed Load Vehicle Reg	187,357
9	E-Plate Reg	32,693
10	School Bus Reg	4,866
11	Light Trailer Reg	14,314,240
12	Heavy/Special/Rental Trailer Reg	265,084
13	Light Titles - New/First OR/Transfer	140,733,179
14	Heavy Titles - New/First OR/Transfer	3,654,763
15	Motor Carrier Interstate Reg	58,988,864
16	Motor Carrier Intrastate Reg	24,489,529
17	Motor Carrier Trip Permits	8,688,481
18	Weight-Mile Tax (includes late fees)	595,237,237
19	Road Use Assessment Fee	4,648,781
20	Weight Receipts	7,244,413
21	Gas Tax	951,703,440
22	Use Fuel (diesel) Tax	99,554,088

forecast into the yellow-shaded cells because the revenues by summary revenue source will automatically calculate the revenue control totals in the left-most summary table of the *Revenue Forecast* tab. The revenue control totals are used to attribute revenues to the vehicle classes. The Registration Fee revenues and the Other MC revenue totals are set equal to the control totals in the revenue attribution calculations.

**RATES**

The *Rates* tab contains revenue instrument rates (tax rates and fees) that are used in the revenue attribution calculations along with other revenue inputs in the *Revenue Forecast* (revenue control totals) and *General* (evasion rates, etc.) tabs.

The tax and fee rates for the revenue instruments are located in the *Rates* tab. Each of the revenue rates is used with its corresponding vehicle tax class VMT to calculate or attribute revenues to the vehicle classes. The current law rates can be found in the Revised Oregon Statutes or obtained from ODOT publications.

The gas and diesel tax rates are entered as dollars per gallon. The VMT tax, WMT tax, and RUAF are entered as dollars per mile. Oregon

does not currently have a VMT tax so rates are entered as zero for this instrument. The WMT tax and RUAF will vary by weight class and should be entered following the WMT tables or by calculating the weight class rate using the mid-point weight for the weight class.

Registration fees are entered as dollars per year. Divide the two-year registration fee by two to annualize the registration fee. The Normal Reg is the passenger vehicle registration fee for basic vehicles. The Heavy Vehicle Registration Fee table is for vehicles 10,001 pounds and greater.

Public vehicles are required to pay a one-time registration fee of \$2. The E-Plate Reg fee is set to \$0.40 per year, using the assumption that each public vehicle has a 5-year service life.

The title fee is entered as dollars per transaction. The light vehicle title fee is used for weight classes 24,001 pounds and under, and the heavy vehicle title fee is used for weight classes 26,001 pounds and greater.

The annual flat fee rates per 100 pounds are converted to monthly rates for each weight class by dividing by 12 (months per year) and using the mid-point of the weight category to calculate the rate for the weight class.

**Figure 52. Rates**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Rates															RUAF Rate		
2	Weight Class	Axles	Gas Tax (per gallon)	Use Fuel Tax (per gallon)	VMT Tax	WMT Rate	Normal Reg	Farm Reg	Tow Reg	CN Reg	E-Plate Reg	LT Reg	HT Reg	Title	Weight Class	Axles	RUAF Rate	
3		1	0	0.30	0.00	0.0000	43	35	43	43	0.40	43	0	77	1	0	0.0000	
4	10,001	0	0.30	0.30	0.00	0.0000	391	53	122	60	0.40	43	0	77	10,001	0	0.0000	
5	12,001	0	0.30	0.30	0.00	0.0000	438	68	132	65	0.40	43	0	77	12,001	0	0.0000	
6	14,001	0	0.30	0.30	0.00	0.0000	485	76	153	75	0.40	43	0	77	14,001	0	0.0000	
7	16,001	0	0.30	0.30	0.00	0.0000	532	91	163	80	0.40	43	0	77	16,001	0	0.0000	
8	18,001	0	0.30	0.30	0.00	0.0000	593	99	183	90	0.40	43	0	77	18,001	0	0.0000	
9	20,001	0	0.30	0.30	0.00	0.0000	640	114	193	95	0.40	43	0	77	20,001	0	0.0000	
10	22,001	0	0.30	0.30	0.00	0.0000	703	121	214	105	0.40	43	0	77	22,001	0	0.0000	
11	24,001	0	0.30	0.30	0.00	0.0000	764	137	224	110	0.40	43	0	77	24,001	0	0.0000	
12	26,001	0	0.30	0.30	0.00	0.0498	375	144	244	120	0.40	0	10	90	26,001	0	0.0000	
13	28,001	0	0.30	0.30	0.00	0.0528	391	159	255	125	0.40	0	10	90	28,001	0	0.0000	
14	30,001	0	0.30	0.30	0.00	0.0552	422	167	275	135	0.40	0	10	90	30,001	0	0.0000	
15	32,001	0	0.30	0.30	0.00	0.0576	438	182	285	140	0.40	0	10	90	32,001	0	0.0000	

### MPG

There are two *MPG* tabs (one in the inputs workbook and one in the outputs workbook) that contain initial assumed MPG (input) and adjusted MPG (output) by weight class.

In the inputs workbook, the assumed MPG values in the yellow-shaded cells were derived from a regression analysis of the Vehicle Inventory and Use Statistics (VIUS) 2002 data (U.S. Census Bureau). VIUS data collection was discontinued after 2002. The MPG assumptions by weight class can be updated when better information or data on MPG by weight class become available; no standardized method for updating this tab has been developed.

The assumed MPG are used in the initial allocation of fuel tax revenues by weight class in the model (see columns A and B in [Figure 53](#)). Gasoline and diesel fuel tax revenues are attributed separately because the model allows for different tax rates and different evasion/avoidance assumptions for the two fuel types. VMT by fuel type and weight class for fuel-tax paying vehicles are assembled and adjusted for evasion/avoidance. A preliminary attribution is made by dividing the adjusted VMT in each

combination of weight class and fuel type by the assumed miles per gallon for that weight class from the *MPG* tab and multiplying the resulting number of gallons by the per-gallon rate for that fuel type. The attribution to vehicles between 10,001 and 26,000 pounds is then adjusted to bring those weight classes, as a group, to equity (before considering subsidies). The revenue attributed to basic vehicles is adjusted so that the total revenue attributed equals the forecast revenues from the budget. The implied miles per gallon after adjustment for each weight class is calculated and saved in *MPG* tab in the outputs workbook where it may be examined for reasonableness (see columns D and E in [Figure 53](#)). Adjusted MPG is also a set of MPG values (by weight class) adjusted to account for the wide variation in VMT for 10,000-26,000-pound vehicles. The reasons for using this approach are detailed in Issue Paper 6 of the 2007 HCAS.

### POLICY

The *Policy* tab contains the allocator or allocators applied to each work type. The user may change the yellow-shaded cells in the work type-allocator table for the allocator name and

the allocator share for each work type. Available allocators are listed to the right of the main table. Note that all allocators must be entered exactly as shown (spaces, spelling, etc.) for the model to function properly; the user should copy and paste allocator names into the yellow-shaded allocator name columns to avoid errors.

The user may enter the allocator share (a percent value between 0 and 100 percent) for the first allocator; the percentage for a second allocator is automatically calculated as 100 percent minus the percentage for the first allocator. Do not change this; the allocator percentages must add to exactly 100 percent.

The Preliminary and Construction Engineering and Right of Way allocators are updated using the calculations from the supplemental Split PE and ROW workbook. Pavement work type allocators are from the pavement factors developed by RD Mingo and Associates.

### CODES

The *Codes* tab has Summary Work Types (SWT) and the Summary Weight Class lookup tables which are used by the model to aggregate the costs to allocate and allocated costs.

**Figure 53. Initial and Adjusted MPG**

Inputs Workbook		Outputs Workbook	
A	B	D	E
Declared	MPG	Weight Class	Adjusted MPG
1			
2	1	1	20.89
3	10,001	10,001	15.53
4	12,001	12,001	14.69
5	14,001	14,001	13.97
6	16,001	16,001	13.35
7	18,001	18,001	12.79
8	20,001	20,001	12.29
9	22,001	22,001	11.83
10	24,001	24,001	11.42
11	26,001	26,001	7.15
12	28,001	28,001	7.04
13	30,001	30,001	6.94
14	32,001	32,001	6.85
15	34,001	34,001	6.76
16	36,001	36,001	6.67
17	38,001	38,001	6.59

**Figure 54. Policy**

	A	B	C	D	E	F
	Work Type	Allocator 1	Share 1	Allocator 2	Share 2	
1	Work Type Description					
2	Preliminary and Construction Engineering (and etc.)	1	CongestedPCE	0.5595 Other_Construction	0.4405	
3	Right of Way (and Utilities)	2	CongestedPCE	0.7375 Other_Construction	0.2625	
4	Grading and Drainage	3	CongestedPCE	1.0000 None	0.0000	
5	New Pavements-Rigid	4	CongestedPCE	0.0399 Rigid	0.9601	
6	New Pavements-Flexible	5	CongestedPCE	0.0543 Flex	0.9457	
7	New Shoulders-Rigid	6	CongestedPCE	1.0000 None	0.0000	
8	New Shoulders-Flexible	7	CongestedPCE	1.0000 None	0.0000	
9	Pavement and Shoulder Reconstruction-Rigid	8	CongestedPCE	0.0399 Rigid	0.9601	
10	Pavement and Shoulder Reconstruction-Flexible	9	CongestedPCE	0.0543 Flex	0.9457	
11	Pavement and Shoulder Rehab-Rigid	10	All_VMT	0.0399 Rigid	0.9601	
12	Pavement and Shoulder Rehab-Flexible	11	All_VMT	0.0543 Flex	0.9457	
13	Pavement and Shoulder Rehab-Other	12	All_VMT	1.0000 None	0.0000	
14	New Structures	13	None	1.0000 None	0.0000	
15	Replacement Structures	14	None	1.0000 None	0.0000	
16	Structures Rehabilitation	15	None	1.0000 None	0.0000	

**Figure 55. Codes**

	A	B	C	D	E
	Summary Work Types	Summary	Summary Weight Classes	Summary	Summary
	Work Type	Work Type	Weight Class	Weight Class	
1					
2	0	21	1	1	
3	1	17	8,001	1	
4	2	22	10,001	10,001	
5	3	12	12,001	10,001	
6	4	12	14,001	10,001	
7	5	13	16,001	10,001	
8	6	12	18,001	10,001	
9	7	12	20,001	10,001	
10	8	12	22,001	10,001	
11	9	15	24,001	10,001	
12	10	18	26,001	28,001	
13	11	20	28,001	28,001	
14	12	18	30,001	28,001	
15	13	3	32,001	28,001	
16	14	3	34,001	28,001	
17	15	3	36,001	28,001	
18	16	14	38,001	28,001	
19	17	12	40,001	28,001	

## II. OUTPUT FILES

After the user has finished updating the inputs workbook for their scenario, the user must save the workbook in the *inputs* folder as specified earlier in this guide (see [Section 4, Initial Model Setup](#) and [Section 6, Set Up a New Scenario](#)). After the user has set up a new scenario, the user must run the scenario through the HCAS Python model. Steps to run the HCAS Python model are outlined in [Section 7, Run the HCAS Python Model](#).

Once the HCAS Python model has finished running, the user may open the scenario's *outputs* folder and open the outputs workbook that will have the scenario's name in its filename (e.g., "HCAS Outputs 2015 Scenario 1.xlsx"). The outputs workbook will have detailed and summary data on the VMT analysis, allocated costs, and attributed revenues from the model. There are also detailed text output files that are saved in the *txt\_2015* folder.

### AUDITING

Recalculating the model and saving the outputs should take a few minutes. Once the model results have been recalculated there are several checks that can be performed to audit the model calculations. After the model has successfully completed, review the model results to check that the VMT, cost allocation, and revenue attribution in the output tabs are reasonable.

The following are general checks that can be performed to audit the model output:

Check that the costs to allocate (the non-project costs, project costs, and local costs data entered into the model by the user) are equal to the allocated costs from the model. If costs to allocate are different from the allocated costs, go back to the non-project costs, project costs, and local costs tabs to check that all costs were entered with valid work types, funding sources, functional systems, and bridge types.

Check the reasonableness of the adjusted MPG rates compared to the initial assumed MPG by weight class on the *MPG* tab in the outputs workbook.

Check to see if any pavement factors are listed as missing by reviewing the *MissingPavementFactors.log* file in the *txt\_2015* folder. If the *MissingPavementFactors.log* file does have missing pavement factors listed, check the pavement factors input file.

Attributed Revenues for Registration fees and Other MC in the *Attributed Revenues* tab in the outputs workbook should equal their control totals from the *Revenue Forecast* tab in the inputs workbook.

### OUTPUT WORKBOOK TABS

Running the HCAS Python model will produce a new outputs workbook with model outputs and summary results.

#### Model VMT

The *Model VMT* tab contains the projected VMT in the forecast year by vehicle weight class and vehicle tax class. This table is analogous to the table in the *Base VMT* input tab but for the model year. The VMT growth rates are applied to the Base VMT to produce the Model VMT output.

Figure 56. Model VMT

	A	B	C	D	E	F	G	H	I	J	K
2	Weight Class	Private Passenger	Gas Commercial 8-26	Diesel & Other Commercial 8-26	Gas Tow Trucks	Diesel & Other Tow Trucks	RUAFL Vehicles	Flat Fee Vehicles Log	Flat Fee Vehicles S&G	Flat Fee Vehicles Chip	VMT Vehicles 26-60 Any Axle
3	1	32,251,303,582	0	0	0	0	0	0	0	0	0
4	10,001	19,702,776	45,840,455	52,780,740	454,052	1,199,994	0	0	0	0	0
5	12,001	13,059,017	19,240,148	38,554,392	372,971	1,491,884	0	0	0	0	0
6	14,001	35,766,790	28,008,123	80,640,672	551,349	2,610,798	0	0	0	0	0
7	16,001	22,190,413	9,854,710	47,964,528	145,945	1,751,343	0	0	0	0	0
8	18,001	18,051,537	7,780,034	48,335,006	145,945	2,789,175	0	0	0	0	0
9	20,001	0	2,741,536	11,633,004	48,648	502,700	0	0	0	0	0
10	22,001	8,307,932	4,593,925	16,671,502	16,216	827,023	0	0	0	0	0
11	24,001	10,066,955	16,671,502	143,572,504	437,836	10,686,433	0	0	0	0	0
12	26,001	2,516,480	0	0	0	0	0	5,843	0	0	1,277,552
13	28,001	4,587,697	0	0	0	0	0	0	0	0	3,703,887
14	30,001	14,736,282	0	0	0	0	0	0	0	0	9,112,784
15	32,001	0	0	0	0	0	0	0	0	0	24,648,877
16	34,001	0	0	0	0	0	0	0	0	0	4,348,035
17	36,001	0	0	0	0	0	0	0	0	0	4,791,243
18	38,001	0	0	0	0	0	0	0	0	0	6,813,337
19	40,001	0	0	0	0	0	0	0	0	0	6,132,121
20	42,001	0	0	0	0	0	0	0	0	0	4,290,966
21	44,001	0	0	0	0	0	0	0	333	0	36,568,868
22	46,001	0	0	0	0	0	0	0	124,810	0	15,228,160
23	48,001	0	0	0	0	0	0	0	0	0	15,187,191
24	50,001	0	0	0	0	0	0	0	15,752	0	15,854,551
25	52,001	0	0	0	0	0	0	0	0	0	30,823,833

#### Costs to Allocate by SWT

The *Costs to Allocate by SWT* tab (see [Figure 57](#) on the following page) displays a summary table of the input data in the *Project Costs*, *Non-Project Costs*, and *Local Costs* tabs by summary work type. While the model combines the cost input data from the three tabs from the inputs workbook to produce this summary table, no other calculations are performed on the input data to produce the *Costs to Allocate by SWT* tab. The tabulated costs from all funding sources on the *Costs to Allocate by SWT* tab are compared with the output on the *Allocated Costs by SWT* tab to ensure that all input costs are allocated in the model calculations. The *Costs to Allocate by SWT* tab is also used to create exhibits in the final HCAS report.

Figure 57. Costs to Allocate by SWT

	A	B	C	D	E	F	G
3	<b>Summary Work Type</b>	<b>Bond</b>	<b>Federal</b>	<b>Local-Federal</b>	<b>Local-Other</b>	<b>Local-State</b>	<b>State</b>
4	Admin	6,398,786	6,398,166	22,881,769	15,669,929	120,788,280	594,973,380
5	Bike and Pedestrian	0	42,791,867	175,979	120,514	928,958	11,404,562
6	Bridge-bridge and interchange	3,078,183	153,370,965	351,369	240,625	1,854,806	14,159,600
7	Bridge-bridge maintenance	0	14,922,283	0	0	0	1,707,922
8	Fish	153,578	21,089,803	0	0	0	2,390,897
9	Hwy Planning	0	285,388	0	0	0	32,664
10	Hwy Safety	0	22,551,911	0	0	0	1,400,000
11	Maintenance	0	26,211,554	1,879,759	1,287,300	9,922,871	313,067,716
12	Maintenance-bridge maintenance	0	4,416,020	0	0	0	19,081,840
13	Maintenance-other pavement	0	472,759	0	0	0	39,984
14	Maintenance-pavement maintenance	0	3,094,216	45,459,211	31,131,449	239,819,109	124,292,644
15	Modernization	15,960,855	211,953,870	13,590,144	9,306,824	71,739,650	47,953,649
16	Modernization-new pavement	16,974,693	66,939,718	773,750	529,881	4,084,472	8,665,319
17	Modernization-other pavement	0	0	0	0	0	0
18	Modernization-pavement and shoulder	0	54,275,120	0	0	0	3,371,592
19	Multimodal	0	0	0	0	0	0
20	PE	156,503	75,977,486	941,845	644,996	4,926,992	18,834,515
21	Preservation	0	0	0	0	0	0
22	Preservation-other pavement	0	0	0	0	942,786	8,570,779
23	Preservation-pavement and shoulder	0	105,922,153	2,764,703	1,893,328	13,847,316	5,342,440
24	Prior Alloc'd Bonds	392,009,761	0	0	0	0	0
25	ROW	413,370	25,115,052	232,073	158,929	1,225,067	7,111,207
26	Transit	0	61,383,493	0	0	0	5,888,744
27	Unknown	0	12,671,072	0	0	0	114,905,869
28	<b>Costs to Allocate Total</b>	<b>434,199,728</b>	<b>909,842,896</b>	<b>89,050,601</b>	<b>60,983,774</b>	<b>470,080,307</b>	<b>1,303,195,223</b>
29	<b>Annual Expenditures (thousands)</b>	<b>217,100</b>	<b>454,921</b>	<b>44,525</b>	<b>30,492</b>	<b>235,040</b>	<b>651,598</b>

Figure 58. Allocated Costs by SWT

	A	B	C	D	E	F	G	H	I	J
2										
3	<b>Funding</b>	<b>Summary Work Type</b>	<b>1</b>	<b>10,001</b>	<b>26,001</b>	<b>78,001</b>	<b>80,001</b>	<b>104,001</b>	<b>105,501</b>	<b>Total</b>
4	bond	Other	4,997,797	127,995	62,269	173,970	49,007	41,271	477	5,452,786
5	bond	Other	0	0	0	0	0	140,688	175,647	3,078,183
6	bond	Bridge	1,980,035	188,694	87,399	330,140	175,599	140,688	175,647	3,078,183
7	bond	Bridge	0	0	0	0	0	0	0	0
8	bond	Other	138,884	4,107	1,902	7,185	1,935	1,550	16	153,578
9	bond	Other	0	0	0	0	0	0	0	0
10	bond	Other	0	0	0	0	0	0	0	0
11	bond	Maintenance	0	0	0	0	0	0	0	0
12	bond	Maintenance	0	0	0	0	0	0	0	0
13	bond	Maintenance	0	0	0	0	0	0	0	0
14	bond	Maintenance	0	0	0	0	0	0	0	0
15	bond	Modernization	4,112,318	1,252,731	740,376	4,303,537	3,180,829	1,917,306	483,757	15,960,855
16	bond	Modernization	2,492,838	1,402,157	943,486	5,707,248	3,586,070	2,695,857	167,035	16,974,693
17	bond	Modernization	0	0	0	0	0	0	0	0
18	bond	Modernization	0	0	0	0	0	0	0	0
19	bond	Other	0	0	0	0	0	0	0	0
20	bond	Other	108,226	6,831	4,287	19,955	8,773	7,006	1,446	158,503
21	bond	Preservation	0	0	0	0	0	0	0	0
22	bond	Preservation	0	0	0	0	0	0	0	0
23	bond	Preservation	0	0	0	0	0	0	0	0

Figure 59. Allocated Costs

	A	B	C	D	E	F	G	H	I	J
2	<b>Weight Class</b>	<b>Axes</b>	<b>Bond</b>	<b>Federal</b>	<b>Local-Federal</b>	<b>Local-Other</b>	<b>Local-State</b>	<b>Other</b>	<b>State</b>	<b>Total Allocated Costs</b>
3	1	0	221,548,338	518,668,122	51,681,894	35,392,877	273,475,961	138,439,276	974,907,408	2,075,674,595
4	10,001	0	3,186,487	4,379,132	323,665	221,653	1,704,579	1,701,960	4,459,680	14,255,195
5	12,001	0	2,326,401	3,077,872	289,298	198,118	1,523,144	1,136,528	3,020,748	10,435,580
6	14,001	0	4,104,784	7,356,245	742,656	506,587	3,909,111	2,407,028	6,620,952	23,242,336
7	16,001	0	2,393,163	4,391,082	522,894	358,069	2,751,940	1,361,383	3,788,494	14,205,663
8	18,001	0	2,388,956	5,008,026	680,006	465,683	3,578,386	1,466,395	4,122,616	16,243,672
9	20,001	0	849,484	1,588,197	266,384	182,425	1,401,857	421,318	1,222,644	5,490,790
10	22,001	0	1,296,238	3,064,435	544,509	372,892	2,864,931	772,776	2,261,539	10,404,545
11	24,001	0	5,815,248	20,896,091	4,137,149	2,833,209	17,766,432	4,820,203	14,487,486	69,715,613
12	26,001	0	1,019,686	1,005,580	166,647	114,124	876,958	266,805	1,474,457	4,657,452
13	28,001	0	995,566	1,993,592	380,733	260,734	510,683	2,773,596	8,407,636	8,407,636
14	30,001	0	1,932,653	2,501,410	496,432	339,967	2,612,197	627,548	3,461,814	11,344,473
15	32,001	0	1,326,243	2,505,038	493,129	337,705	2,594,645	592,827	3,062,614	10,319,376
16	34,001	0	576,788	882,709	153,773	105,307	809,142	204,858	1,138,302	3,866,020
17	36,001	0	591,269	1,184,334	258,032	176,706	1,357,708	264,945	1,522,806	5,090,854
18	38,001	0	698,269	1,311,328	165,055	113,033	868,539	315,022	1,668,119	4,824,343
19	40,001	0	270,926	765,006	116,947	80,088	615,342	169,146	958,484	2,806,793
20	42,001	0	854,771	478,977	81,126	55,557	428,853	114,160	582,149	2,189,033
21	44,001	0	1,839,960	3,073,689	494,762	338,824	2,803,260	728,381	3,689,355	12,019,850
22	46,001	0	1,094,758	1,447,475	234,649	160,893	1,234,643	349,061	1,770,838	5,943,053
23	48,001	0	1,121,236	1,376,155	232,174	158,997	1,221,804	332,337	1,679,283	5,789,449
24	50,001	0	835,113	1,435,702	249,135	170,613	1,310,800	334,052	1,845,965	5,847,327
25	52,001	0	1,594,797	2,750,135	446,384	305,693	2,348,619	847,949	3,173,528	10,619,156
26	54,001	0	1,700,495	2,544,839	425,202	291,187	2,237,143	595,729	2,906,514	10,105,379

Allocated Costs by SWT

The *Allocated Costs* by SWT tab displays the model output of the allocated costs by summary work type, funding source, and summary weight class. The allocated costs on this tab are the same allocated costs displayed in the *Allocated Costs* tab and in the Allocated Cost output text files. Whereas the *Allocated Costs* tab contains the allocated costs for every weight class, the *Allocated Costs by SWT* tab has a summary table to create exhibits in the final HCAS report.

**Allocated Costs**

The *Allocated Costs* tab displays the costs allocated in the model for each funding source to each weight class and axle class. This tab does not contain any information on the work types of the allocated costs. The output on the *Allocated Costs* tab is used in the *Equity* and *Summary* tabs to determine cost responsibility by weight class and user groups.

**Attributed Revenues**

The *Attributed Revenues* tab displays the attributed user fees by major revenue source for each weight class and axle class. The revenue totals are calculated in the Attribute Revenues calculations in the model. The output on the *Attributed Revenues* tab is used in the *Equity* tab and *Summary* tab to determine annual user fees and share of revenues for each vehicle class.

**MPG**

The *MPG* tab in the outputs workbook is discussed in the previous section on page D29 and illustrated in Figure 53.

Figure 60. Attributed Revenues

	A	B	C	D	E	F	G	H	I	J	K
2	<b>Weight Class</b>	<b>Axes</b>	<b>Gas Tax</b>	<b>Diesel Tax</b>	<b>WMT</b>	<b>Flat Fee</b>	<b>RUF</b>	<b>Registration</b>	<b>Other MC</b>	<b>Subsidy</b>	<b>Full Fee VMT</b>
3	1	0	919,921,791	47,184,812	0	0	0	472,349,600	0	9,186,820	32,251,309,582
4	10,001	0	6,000,108	4,784,631	0	0	0	4,107,359	0	256,772	118,323,971
5	12,001	0	3,310,392	3,719,277	0	0	0	2,668,654	0	648,072	70,833,557
6	14,001	0	6,534,451	8,161,236	0	0	0	6,114,082	0	1,038,081	144,415,585
7	16,001	0	3,267,794	5,114,430	0	0	0	3,603,323	0	322,125	80,009,652
8	18,001	0	2,808,177	5,609,788	0	0	0	3,904,726	0	486,274	74,166,377
9	20,001	0	4,699,800	1,413,106	0	0	0	896,170	0	686,251	14,473,539
10	22,001	0	1,700,247	2,164,674	0	0	0	1,927,560	0	444,297	29,573,359
11	24,001	0	3,989,949	18,416,572	0	0	0	10,989,563	0	2,892,046	170,310,960
12	26,001	0	330,619	64,201	120,882	2,173	0	132,076	10,742	1,630,931	3,799,875
13	28,001	0	593,991	123,986	371,574	0	0	267,852	31,144	2,837,769	8,291,584
14	30,001	0	1,411,923	172,255	955,749	0	0	433,880	76,624	2,357,740	23,849,066
15	32,001	0	81,450	121,851	2,697,573	0	0	894,582	207,259	998,196	24,648,877
16	34,001	0	110,742	41,475	494,850	0	0	166,556	1,099,048	4,348,835	10,995,048
17	36,001	0	43,323	46,623	573,512	0	0	166,024	40,287	1,597,969	4,791,243
18	38,001	0	58,417	104,152	846,625	0	0	329,379	57,290	1,694,835	6,813,337
19	40,001	0	36,590	31,148	788,775	0	0	246,558	51,562	669,884	6,132,121

### SUMMARY WORKBOOK TABS

The *Equity* and *Summary* tabs summarize the model output tabs, displaying summary results and equity ratios. These tabs reference the model output tabs and do not require any user input.

#### Equity

The *Equity* tab contains the Annual VMT, Annual Cost Responsibility, Annual User Fees, and Equity Ratios for each 2,000-pound weight class. The VMT, Cost Responsibility, and User Fee Revenues are shown for All Vehicles and for Full-Fee Vehicles.

Full-Fee Costs are calculated by scaling total Cost Responsibility by the ratio of full-fee VMT to total VMT. The Full-Fee Scaled Equity Ratio is the ratio of the share of full-fee cost responsibility to the full-fee user fee share.

Figure 61. Equity

Weight Class	Axle	All	Annual VMT		State	Annual Cost Responsibility		All	Annual User Fees		All	Full-Fee Scaled Equity Ratio
			Full-Fee	Alternative Fee		Federal	Local		Full-Fee	Subsidy		
4	1 to 10,000	32,927,262.617	32,251,355.562	675,905.020	589,227.871	259,334.051	160,275.390	719,720.102	703,492.020	4,559,410	1,016,301.000	0.9374
5	10,001 to 20,000	130,921,430	118,263,971	12,657,459	3,813,004	2,199,369	1,724,360	7,446,049	6,845,610	529,399	8,441,760	1.5167
6	20,001 to 30,000	80,994,847	70,803,907	10,190,920	2,872,504	1,539,838	1,056,200	4,846,161	4,207,338	264,056	4,346,073	1.4168
7	30,001 to 40,000	167,183,842	144,418,888	22,764,957	9,382,888	3,878,123	2,860,177	10,402,884	9,437,262	973,641	10,239,616	1.3434
8	40,001 to 50,000	88,389,789	80,028,682	8,361,107	3,590,829	2,196,341	1,616,462	8,902,773	8,326,832	575,941	8,738,664	1.2282
9	50,001 to 60,000	69,899,151	74,168,877	14,269,824	3,288,788	2,824,013	2,392,027	1,161,348	9,288,408	263,127	9,791,486	1.2088
10	60,001 to 70,000	23,982,598	14,374,839	9,607,618	1,538,064	788,088	629,233	1,386,838	1,038,884	343,126	1,848,832	0.8887
11	70,001 to 80,000	38,024,828	26,973,289	11,051,576	1,778,889	1,022,218	1,091,160	2,086,249	2,389,290	222,146	3,919,219	0.8887
12	80,001 to 90,000	219,082,828	170,310,662	48,772,166	10,041,267	10,448,048	14,388,304	18,808,402	14,104,863	4,648,023	27,097,818	0.7438
13	90,001 to 100,000	18,367,738	3,798,878	14,568,860	1,847,072	302,790	878,864	392,346	298,896	876,483	480,978	0.7928
14	100,001 to 110,000	28,054,128	8,291,884	20,262,244	1,894,581	989,799	1,322,441	694,273	522,184	1,418,868	1,038,669	0.7198
15	110,001 to 120,000	30,001,917	23,849,096	17,960,881	2,897,274	1,250,728	1,724,008	1,825,818	1,641,349	1,178,870	3,233,217	0.6918
16	120,001 to 130,000	34,152,289	24,948,877	9,203,408	2,184,428	1,250,319	1,712,740	2,291,268	1,804,068	489,098	3,722,941	0.6928
17	130,001 to 140,000	13,225,208	6,248,228	6,976,980	887,643	451,264	306,111	628,091	302,399	949,944	652,453	0.7888
18	140,001 to 150,000	17,783,585	12,362,241	5,421,344	1,037,208	562,167	896,222	438,684	332,428	796,964	685,768	0.6928
19	150,001 to 160,000	18,071,706	8,813,237	12,258,474	1,163,794	605,804	973,214	697,921	502,672	947,417	801,742	0.9100
20	160,001 to 170,000	10,722,384	6,132,121	4,590,274	614,202	362,523	514,256	377,316	326,942	602,800	602,800	1.0000
21	170,001 to 180,000	6,404,116	4,289,896	2,113,148	373,460	238,289	281,768	480,096	387,576	68,460	733,382	0.7183
22	180,001 to 190,000	40,021,045	36,362,210	3,658,835	2,354,658	1,836,844	1,716,423	3,045,213	3,671,420	70,752	8,490,700	0.9657
23	190,001 to 200,000	15,828,687	15,362,910	4,466,171	1,158,717	723,737	814,662	1,817,668	1,524,300	150,881	2,338,338	0.9188
24	200,001 to 210,000	18,402,408	15,187,191	3,215,215	1,402,259	888,078	808,387	1,773,539	1,541,277	90,832	2,389,226	0.9210
25	210,001 to 220,000	17,148,499	15,870,223	1,278,199	1,240,539	717,891	695,214	1,234,487	1,541,294	38,084	2,613,544	0.8978
26	220,001 to 230,000	33,266,172	30,823,833	2,442,339	2,384,163	1,378,099	1,850,348	3,453,617	3,277,767	88,866	4,450,769	0.9522
27	230,001 to 240,000	30,137,319	28,028,810	2,108,509	2,303,904	1,272,419	1,476,768	3,216,200	3,185,302	150,216	4,710,873	0.9963
28	240,001 to 250,000	9,878,582	9,878,582	278,091	774,758	492,000	692,622	1,127,817	1,119,810	24,274	1,894,220	0.9447
29	250,001 to 260,000	9,847,223	9,220,740	626,483	711,044	400,605	467,010	1,104,223	1,074,228	29,010	1,500,978	0.9999
30	260,001 to 270,000	1,798,249	1,708,830	89,419	132,029	87,240	70,253	210,487	203,421	2,880	207,331	1.1318
31	270,001 to 280,000	3,026,788	3,026,788	199,547	600,300	505,014	635,400	1,230,567	1,217,713	28,857	1,937,677	0.9764
32	280,001 to 290,000	6,003,071	6,003,071	341,053	896,308	505,014	635,400	1,230,567	1,217,713	28,857	1,937,677	0.9764
33	290,001 to 300,000	2,840,019	2,478,817	361,202	239,890	138,648	179,613	342,396	337,870	3,894	641,988	0.8918
34	300,001 to 310,000	4,378,181	4,277,801	100,380	608,888	219,460	230,380	894,928	887,881	13,640	883,184	0.9988
35	310,001 to 320,000	3,887,804	3,787,152	70,652	383,424	224,421	181,182	881,208	878,219	4,918	728,688	1.1124
36	320,001 to 330,000	2,713,244	2,638,883	74,361	190,441	121,781	48,307	428,841	420,281	3,504	248,647	1.7282
37	330,001 to 340,000	7,000,000	8,888,888	1,888,888	1,888,888	448,409	378,000	1,188,080	1,188,080	20,000	1,378,000	1.0000

Figure 62. Summary

Declassed Weight	All	Annual VMT		State	Annual Cost Responsibility		All	Annual User Fees		All	Scaled Equity Ratio				
		Full-Fee	Alternative Fee		Federal	Local		Full-Fee	Subsidy						
4	1 to 10,000	32,927,262.617	32,251,355.562	675,905.020	589,227.871	259,334.051	160,275.390	719,720.102	703,492.020	4,559,410	1.0091				
5	10,001 to 20,000	843,271,225	702,028,201	141,247,024	31,052,458	24,870,540	26,073,697	66,659,482	51,838,035	48,961,588	3,346,959	0.9909			
6	20,001 to 30,000	412,349,237	283,024,370	127,324,961	26,512,096	15,948,136	18,226,325	44,773,542	38,012,994	28,296,277	7,389,701	0.7048			
7	30,001 to 40,000	1,461,993,981	1,219,899,842	629,119,456	62,976,456	76,505,581	30,871,965	219,964,976	207,505,053	209,603,899	1,361,123	1.3423			
8	40,001 to 50,000	322,878,314	318,963,924	2,912,390	50,930,136	40,921,724	23,456,460	118,210,493	56,582,874	36,344,132	261,800	0.7018			
9	50,001 to 60,000	271,938,389	265,622,107	6,286,282	44,663,687	30,865,600	23,975,266	97,221,080	50,456,970	49,828,437	550,834	0.7377			
10	60,001 to 70,000	1,145,854	1,145,854	0	6,860,800	6,860,800	3,240,323	3,240,323	3,240,323	0	2,348	0.3469			
11	Total	33,924,894,615	34,562,935,779	961,898,836	868,697,476	454,921,448	310,657,342	1,574,666,517	1,122,695,726	1,101,681,653	10,829,281	1.0000			
13	10,001 and up	2,997,031,998	2,711,027,137	285,938,861	270,460,605	195,587,347	129,781,976	557,534,832	409,971,624	395,241,634	12,233,871	0.9841			
14	20,001 to 80,000	1,556,424,218	1,428,933,112	139,488,100	140,702,549	92,048,717	51,313,779	264,742,109	237,878,437	234,898,176	8,038,298	1.2193			
15	80,001 to 105,500	594,786,702	585,588,031	9,198,671	93,618,823	71,807,324	49,431,796	211,431,579	197,049,845	190,172,569	812,613	0.7183			
16	105,501 to 150,000	1,145,854	1,145,854	0	6,860,800	6,860,800	3,240,323	3,240,323	3,240,323	0	2,348	0.3469			
17	150,001 and up	2,154,358,774	2,008,661,896	144,693,777	239,617,143	170,718,847	103,728,279	491,273,850	447,133,590	444,278,046	8,848,912	0.9820			
20	Declassed Weight	All	Annual VMT	Full-Fee	Alternative Fee	State	Annual Cost Responsibility	Federal	Local	Full-Fee	Annual User Fees	Full-Fee	Subsidy	All	Share of Cost
21	1 to 10,000	32,927,262.617	32,251,355.562	675,905.020	589,227.871	259,334.051	160,275.390	719,720.102	703,492.020	4,559,410	1,016,301.000	0.9374			
22	10,001 to 20,000	843,271,225	702,028,201	141,247,024	31,052,458	24,870,540	26,073,697	66,659,482	51,838,035	48,961,588	3,346,959	0.9909			
23	20,001 to 30,000	412,349,237	283,024,370	127,324,961	26,512,096	15,948,136	18,226,325	44,773,542	38,012,994	28,296,277	7,389,701	0.7048			
24	30,001 to 40,000	1,461,993,981	1,219,899,842	629,119,456	62,976,456	76,505,581	30,871,965	219,964,976	207,505,053	209,603,899	1,361,123	1.3423			
25	40,001 to 50,000	322,878,314	318,963,924	2,912,390	50,930,136	40,921,724	23,456,460	118,210,493	56,582,874	36,344,132	261,800	0.7018			
26	50,001 to 60,000	271,938,389	265,622,107	6,286,282	44,663,687	30,865,600	23,975,266	97,221,080	50,456,970	49,828,437	550,834	0.7377			
27	60,001 to 70,000	1,145,854	1,145,854	0	6,860,800	6,860,800	3,240,323	3,240,323	3,240,323	0	2,348	0.3469			
28	70,001 to 80,000	1,145,854	1,145,854	0	6,860,800	6,860,800	3,240,323	3,240,323	3,240,323	0	2,348	0.3469			
29	80,001 to 90,000	2,840,019	2,478,817	361,202	239,890	138,648	179,613	342,396	337,870	3,894	641,988	0.8918			
30	90,001 to 100,000	4,378,181	4,277,801	100,380	608,888	219,460	230,380	894,928	887,881	13,640	883,184	0.9988			
31	100,001 to 110,000	3,887,804	3,787,152	70,652	383,424	224,421	181,182	881,208	878,219	4,91					

**Bonds2015-2017.txt**

Bond expenditures allocated during the 2015-2017 study. It is important to keep the bond allocation output file because this file becomes an input file for future studies. Running the 2015 model generates the bond file for 2015-2017 that will be used in the 2017 HCAS study, along with the prior bond files from the previous three studies.

**DeclaredPaveFactors.txt**

The *DeclaredPaveFactors.txt* file contains the pavement factors by declared operating weight.

**FlatFeeReport.txt**

*FlatFeeReport.txt* contains a summary of the flat fee revenues and as-if revenues for each flat fee commodity by weight class and axle class.

**MissingPavementFactors.log**

*MissingPavementFactors.log* is an output file that will list any missing pavement factors. This file should be checked during the auditing of the model run. If this file lists missing pavement factors, the weight classes and pavement factor input file should be checked for completeness.

**SubsidiesbyVehClass.txt**

*SubsidiesbyVehClass.txt* is an output file that contains the calculated subsidies by weight class and axle class.

**VMTMaster.txt**

The *VMTMaster.txt* file contains the most disaggregated output of the calculated VMT. VMT are reported for each facility class by ownership, weight class, and axle class. This file is used to report the VMT by county and city ownership.

## 12. POLICY ANALYSIS OF ALTERNATIVE RATES

The HCAS model includes the option to analyze changes in revenue instrument taxes or fees. The Alternative Rate Analysis is an optional analysis; if alternative rates have not been specified in the model, the user should ignore the alternative rate analysis output tabs. This section

provides an explanation of the alternative rate analysis, a detailed description of the revenue instruments and three alternative rate case studies to illustrate the alternative rate analysis.

The Alternative Rate Analysis allows the user to estimate the effects of different road user tax rates and fees by entering the alternative rates in the *Alt. Rates* tab and rerunning the Python file, *HCASModule.py*. In the model calculations, the program calibrates the model to the rates and control totals in the *Rates* and *Revenue Forecast* input tabs, and then evaluates the effect of the modified rates specified by the user in the *Alt. Rates* input tab. The model reports the output from the current rates and alternative rates analyses in separate output tabs.

The HCAS model compares the share of costs for each vehicle class to their share of revenues to calculate the equity ratios. Altering the tax rates does not affect the allocation of costs to user groups.

The HCAS model does not contain any travel demand price elasticities, thus changing the use-related tax rates does not affect the underlying VMT used in the model. Nor does changing the fixed costs associated with owning a vehicle alter the assumed vehicle registrations or vehicle miles traveled.

The process for conducting an alternative rate analysis is straightforward. The general procedure is to:

- Enter the alternative rates in the *Alt. Rates* tab in the inputs workbook and re-save the inputs workbook.
- Run *HCASModule.py* (see [Section 7, Run the HCAS Python Model](#)).
- View the alternative rate results on the *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary* tabs in the outputs workbook.

### ALTERNATIVE RATES INPUT TABS

#### Alt. Rates

The *Alt. Rates* tab in the inputs workbook contains the revenue instrument tax rates for gas, diesel, VMT, WMT, and registration fees, the RUAF and flat fee monthly rates, and VMT per month and axle shares. The setup of this tab is the same as the *Rates* tab (see [Figure 52 on page D28](#)).

## Revenue Instruments

In Oregon's current highway finance system, vehicles under 26,001 pounds pay registration fees and the gas or diesel tax, and vehicles over 26,000 pounds pay registration fees and a weight mile tax (WMT).

Other special vehicles classes pay the following combination of use-related taxes and registration fees:

- Charitable non-profit vehicles: pay the charitable non-profit registration and gas or diesel tax.
- E-Plate (publicly owned) vehicles: pay the E-Plate registration fee.
- Tow trucks: Tow-Truck Registration Fee (excludes Tow Truck Certificate Cost), and gas or diesel tax. Tow trucks under 26,000 pounds have their own registration fee schedule; tow trucks over 26,000 pounds register with the MCTD and follow the normal heavy vehicle registration fee schedule.
- Farm vehicles: Farm vehicles have their own Farm Registration Fee Schedule and pay the gas or diesel tax (farm vehicles do not pay the weight-mile tax).
- Flat fee vehicles: Carriers hauling logs, sand and gravel, or wood chips have the option of paying a flat monthly fee based on vehicle weight instead of the weight mile tax. Flat fee vehicles are registered using the Motor Carrier Division registration schedule for tractors, trucks, and buses (normal registration fees).
- Road user assessment fee (RUAF) vehicles: Vehicles operating with single-trip permits at a gross weight above 98,000 pounds pay a RUAF of 5.7 cents per equivalent single-axle load for the loaded portion of their trip and pay a WMT tax for the unloaded portion. These vehicles pay regular registration fees according to their normally declared weight.
- Title fees are one-time fees for new vehicles and title transfers.

Tax rates for each of the unique revenue instruments can be copied from the *Rates* tab into the *Alt. Rates* tab and then modified by the user.

## Gas Tax: Dollars per Gallon

The gas tax rate specified in the *Alt Rates* tab is applied to the imputed gallons of taxed gasoline, which is calculated in the model as the gas tax VMT divided the adjusted MPG.

The gas tax VMT is the sum of the VMT from the following vehicle classes: Gasoline-fueled Basic cars (car VMT minus the portion of basic car minus the assumed diesel share of basic VMT), Gas Commercial (GasCOMM) VMT, Gas Tow Trucks (GasTow) VMT, GasFarm VMT, GasCN VMT, GasSLG, GasFed, and GasSchool.

The total gasoline VMT is adjusted by the gas tax avoidance assumption to determine the total taxed gasoline VMT. The gas tax evasion factor is an assumption specified in the *General* tab.

Key assumptions and data used in the calculation of the gas tax revenues are the percent of basic VMT by diesel-powered vehicles, the gas tax avoidance rate, MPG, VMT and the gasoline tax rates.

The adjusted MPG is calculated by fuel type for each weight class and used in the revenue attribution for the HCAS model is also used in the alternative rate revenue attribution. Thus the revenues from an increase (or decrease) in the gas tax rates is adjusted appropriately so that the gas tax revenues from each vehicle weight class reflect their adjusted MPG and the specified alternative gas tax rate.

A majority of gasoline-powered (and taxed) vehicle miles are basic vehicles. Since the majority of the gas tax vehicle miles are by basic vehicles, increasing the gas tax rate will increase the revenue share paid by basic vehicles and increase the basic vehicle equity share. Similarly, a decrease in the gasoline tax rate will have the opposite effect, decreasing the gasoline tax revenues, which will decrease the basic vehicle share of revenues and the basic vehicle equity ratio.

## Diesel Tax: Dollars per Gallon

The diesel tax rate specified in the *Alt. Rates* tab is applied to the imputed gallons of taxed diesel fuel to determine the diesel tax revenues. The imputed gallons of taxed diesel fuel is calculated as the diesel tax VMT divided by the adjusted MPG.

Diesel tax VMT is calculated as diesel tax evasion and avoidance-adjusted sum of the following vehicle class VMT: Car-Diesel (basic vehicle VMT multiplied by the percent of basic VMT by diesel-powered vehicles), Diesel Comm, DieselTow, DieselFarm, and DieselCN.

The diesel tax, paid by diesel-fueled vehicles, like the gasoline tax, affects both basic and non-basic vehicles; however the majority of diesel-fuel-taxed VMT are by heavy vehicles. In addition to having a higher share of diesel VMT, heavy vehicles also have lower MPG fuel efficiency, which means that heavy vehicles use more fuel per mile. Both of these factors imply that an increase in the diesel tax rate will result in a higher share of revenues for heavy vehicles, all other rates and assumptions held constant.

#### **VMT Tax: Dollars per Mile**

As of January 2015, no VMT tax exists in Oregon, however the VMT tax is a potential future revenue instrument and the model has included the VMT tax instrument as a possible policy option for the alternative rate analysis.

The VMT tax is entered as dollars per mile, similar to the current WMT tax. The VMT tax is applied to all full-fee basic vehicles and non-basic vehicles that do not pay the WMT, Flat Fee, or RUAF tax (e.g., VMT tax is applied to vehicles currently paying either the gasoline or diesel tax).

VMT tax revenues are calculated by applying the VMT tax rates to gas and diesel VMT. A VMT tax can be entered instead of, or in addition to, gas and diesel tax rates. Flat Fee, RUAF, and WMT vehicle classes continue to be taxed using their respective tax instruments and rates.

The impact of a VMT tax on the basic and heavy revenue shares and equity ratio will depend on the VMT tax rates specified for the different weight classes.

#### **Weight Mile Tax (WMT): Dollars per Mile**

The WMT is measured in dollars per mile. The ODOT WMT Table A lists the WMT rates for heavy vehicles between 26,000 and 80,000 pounds and the ODOT WMT Table B contains the per mile rates for heavy vehicles between 80,000 and 105,500 pounds. Vehicles weighing more than 105,500 pounds pay the RUAF.

The WMT revenues and revenue attribution are calculated by multiplying the WMT tax by the WMT evasion-adjusted WMT VMT. Increasing the WMT tax rates will increase the share of revenue for heavy vehicles (vehicles over 26,000 pounds) and increase the heavy vehicle equity ratio. The WMT tax structure will affect the equity ratios for individual weight classes within the heavy vehicle group.

#### **Vehicle Registration Fees: Dollars per Year**

The Oregon DMV registers most vehicles, with the exception of heavy vehicles (over 26,000 pounds), which must register with the MCTD. Vehicle registration fee schedules can be found at the DMV website and the Tractor, Truck, and Buses Registration Fee Schedule can be found at the MCTD website. All registration fees are entered as dollars per year on the *Rates* and *Alt Rates* tabs.

- Normal Vehicle Registration (Normal Reg): Current normal registration for basic vehicles (under 8,000 pounds) is \$84 for a two-year registration (\$43 per year). The MCTD Registration Fee Schedule is used for vehicles 10,000 pounds and up.
- Farm Vehicle Registration (Farm Reg): Certified farm operation vehicles have their own registration schedule (“Fee Schedule: Trucks Registered as Farm Vehicles”).
- Tow Truck Registration (Tow Reg): The fee schedule for tow/recovery vehicles is used for tow trucks under 26,000 pounds, and the registration fee entered in the *Rates* and *Alt Rates* tabs should exclude the tow truck certificate fee. Tow trucks weighing more than 26,000 pounds must register with and pay registration fees according to the MCTD.
- Charitable Non-Profit Registration (CN Reg): per year registration fee. Charitable Non-Profits pay registration fees following the DMV “Fee Schedule For Charitable, Non-Profit and Manufactured Structure Motor Vehicles.” This fee schedule includes vehicles up to 105,500 pounds.
- E-Plate Registration (E-Plate Reg) per year registration fee. Publicly owned vehicles pay a one-time registration fee of \$2. It is assumed that the life of a publicly owned vehicle is five years, thus the annual amount for registration fees is set equal to \$0.40 per year in the 2015 HCAS.

- Light Trailer Registration (LT Reg): The per year registration fee paid by light trailers weighing less than 26,001 pounds.
- Heavy Trailer Registration (HT Reg): The per year registration fee paid by heavy trailers weighing more than 26,000 pounds.

**Title Fee: Dollars per Title Transaction**

A title fee is paid upon first-time purchase and registration of a vehicle in Oregon. As of January 2015 there were two different title fees depending on vehicle class. The title fee for vehicles weighing under 26,000 pounds was \$77 and the fee for vehicles above 26,000 pounds was \$90. The title fee revenue control total amount is attributed to the vehicle classes based on VMT at each weight class and the title fee.

**RUAF: Dollars per Mile**

The Road Use Assessment Fee (RUAF) is a flat rate entered as dollars per equivalent single-axle load (ESAL) by weight class from the RUAF fee schedule. The RUAF rate is applied to the RUAF VMT by weight class, which are tabulated from the base year RUAF collection reports. For a given weight class, the RUAF rates decrease as the number of axles increases because the vehicle weight is being distributed over more axles, causing less road damage.

**Flat Fee: Monthly Fee**

A flat fee is a monthly fee paid by a flat fee commodity hauler. Flat fee rates apply to carriers hauling chips, sand and gravel, or logs. These carriers pay per month according to their loaded operating weight. The Flat Fee rates are entered as dollars per month. The VMT per month and axle share are based on the base year flat fee report data and are used to determine the WMT revenue from flat fee haulers in the “as-if” revenue calculation.

Under the current flat fee rates, log haulers may pay \$7.59 per 100 pounds, sand and gravel haulers may pay \$7.53 per 100 pounds, and wood chip haulers may pay \$30.65 per 100 pounds. Flat fee rates apply to vehicles hauling log, sand and gravel, or chips that are over 26,000 pounds, with the monthly rate calculated as the flat fee rate paid by a hauler operating at the mid-point for the weight category (weight class plus 999 pounds).

**ALTERNATIVE RATES OUTPUT TABS**

The alternative rate analysis results are displayed in three tabs in the outputs workbook: *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary*.

**Alt. Attributed Revenues**

The *Alt. Attributed Revenues* tab contains model output of the attributed revenues by major revenue instrument for each weight and axle class. The *Alt. Attributed Revenues* are summed to produce Annual User Fees in the *Alt. Equity* and *Alt. Summary* tabs.

**Alt. Equity**

The *Alt. Equity* tab displays the Annual VMT, Annual Cost Responsibility, Annual User Fees, and Scaled Equity Ratio by weight and axle class for the alternative rate analysis. The *Alt. Equity* tab refers to the *Alt. Attributed Revenues*, and *Allocated Costs* tabs.

**Alt. Summary**

The *Alt. Summary* tab displays the summary results of the annual model VMT, annual cost responsibility, annual user fees, the subsidy and allocated subsidy, and the equity ratios by aggregated major vehicle weight class for the alternative rate analysis.

**ALTERNATIVE RATES ANALYSIS CASE STUDIES**

This section illustrates three different alternative rate analyses. For each case study, a step-by-step explanation of how to conduct the analysis is provided, followed by a description of the impact of the changes on vehicle equity ratios.

The first case study increases the gas and diesel tax from \$0.30 per gallon to \$0.36 per gallon. The second case study increases the basic vehicle registration fee by \$11, or roughly 25 percent. The third case study imposes a new VMT tax of \$0.0293 per mile, repealing the state fuel tax. The second case study illustrates the effect of a change in a single revenue instrument, while the first and third case studies involve changes to more than one revenue instrument. The net effect of an analysis of two or more revenue instrument rate changes will depend on the relative magnitude of the change to each revenue instrument rate and which vehicle class revenues are affected.

### Case Study A: Change in Gas and Diesel Rates

The first case study considers an increase in the gas and diesel tax from the current rate of \$0.30 per gallon to \$0.36 per gallon—a six-cent increase. Only the gas and diesel tax rates are increased; other revenue instrument rates remain at their 2011 HCAS rates.

Perform an analysis of an increase in the gas and diesel tax rates by following these steps:

- In the *Alt. Rates* tab, copy the current rates from the *Rates* tab.
- In the Gas Tax column (column “C” beginning in row 3) enter 0.36 for each weight class. This step specifies the alternative gas tax rate of \$0.36 per gallon.
- In the Diesel Tax column (column “D” beginning in row 3) enter 0.36 for each weight class. This step specifies the alternative diesel tax rate of \$0.36 per gallon.
- Run HCASModule.py.
- View the alternative rate analysis results in the *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary* tabs in the outputs workbook.

The revenue in the *Alt. Attributed Revenues* tab will now reflect the increase in the gas and diesel tax rates.

**Table 2. Comparison of Annual Revenues for Gas and Diesel Rates Case (thousands of dollars)**

Revenue Source	2011 Rates	Alt. Rates	Revenue Difference	% Change in Revenues
Gas Tax	493,090	591,708	98,618	20%
Diesel Tax	42,798	51,357	8,560	20%
Other	590,345	590,345	0	0%
Total Revenue	1,126,232	1,233,410	107,178	9.5%

**Table 3. Comparison of Revenue Shares and Equity Ratios for Gas and Diesel Rates Case**

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratios	
	2011 Rates	Alt. Rates	2011 Rates	Alt. Rates
1 to 10,000	65.73%	68.42%	0.9954	1.0363
10,001 and up	34.27%	31.58%	1.0089	0.9295

A comparison of the *Equity* tab to the *Alt. Equity* tab shows that the VMT and Cost Responsibility for each weight class have not changed. Only the Attributed Revenues (Annual User Fees) have changed. Because the change in the attributed revenues has also changed the revenue shares, the equity ratios will reflect the shift in the share of revenues attributed to the vehicle classes.

[Table 2](#) compares the gas tax revenue, diesel tax revenue, and other revenue for the 2011 HCAS model (“2011 Rates”) and the alternative gas and diesel rates (“Alt. Rates”). Both the gas tax and diesel tax revenues have increased by 20 percent (a six cent increase in the \$0.30 per gallon fuel tax rate is a 20 percent increase) in the alternative rate analysis, and total revenues have increased by 9.5 percent as a result of the gas and diesel tax rate increases.

In the 2011 HCAS, the basic vehicle equity share is 0.9954. The basic vehicle equity share in the alternative rate analysis (found in the *Alt. Summary* tab after recalculating the model with the alternative rates) is 1.0363 (see [Table 3](#)). The basic vehicle equity share increases because the net effect of the gas and diesel tax increase is an increase in the basic vehicle revenue share, which in turn increases the basic vehicle equity ratio.

### Case Study B: Change in Registration Fee

The second case study, a change in registration fees, considers increasing the normal registration fee for basic vehicles from \$43 to \$54 per year. Only the normal registration fee for basic vehicles is increased; other revenue instrument rates remain at their 2011 HCAS rates.

Perform an alternative rate analysis of a change in the Normal Registration Fee by following these steps:

- In the *Alt. Rates* tab, copy the current rates from the *Rates* tab.
- In the Normal Reg column (column “G” beginning in row 2), enter 54 for Weight Class 1. This step specifies the alternative registration fee of \$54 per year for basic vehicles (vehicles under 10,000 pounds).
- Run HCASModule.py.
- View the alternative rate analysis results in the *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary* tabs in the outputs workbook.

Because the registration fee paid by basic vehicles increases while all other rates are held constant, the basic vehicle share of revenues increases, in turn increasing the basic vehicle equity ratio. Because the heavy vehicle class revenues remain unchanged, the heavy vehicle revenue share declines from 34.3 percent to 33.2 percent, as shown in [Table 4](#).

**Case Study C: Implementation of VMT Tax**

The third case study evaluates the impact of the implementation of a vehicle-mile-traveled (VMT) tax and the repeal of the gas and diesel taxes. Only the gas and diesel taxes and VMT tax are changed; other revenue instrument rates remain at their 2011 HCAS rates.

Perform an alternative rate analysis of a new VMT tax and repeal of the gas and diesel tax by following these steps:

- In the *Alt. Rates* tab, copy the current rates from the *Rates* tab.
- In the Gas Tax and Diesel Tax columns (columns “C” and “D” beginning in row 3), enter 0 for all weight classes. This step sets the gas and diesel tax rates to zero.
- In the VMT Tax column (column “E”, beginning in row 3), enter 0.0293 for all weight classes. This step sets the VMT tax rate to \$0.0293 per mile (2.93 cents per mile).
- Run HCASModule.py.
- View the alternative rate analysis results in the *Alt. Attributed Revenues*, *Alt. Equity*, and *Alt. Summary* tabs in the outputs workbook.

A VMT tax rate of \$0.0293 per mile produces average annual revenues of approximately \$563.1 million. Basic vehicle full-fee revenue share increases to 75.8 percent in the alternative rate analysis from 65.7 percent in the current model.

A VMT tax rate of \$0.0293 per mile is roughly equal to the effective fuel tax rate paid for vehicles with fuel efficiency of 10.5 MPG. Since the majority of the vehicle miles traveled by vehicle tax classes paying the gas and diesel tax are by basic vehicles, in the model assumed to have closer to 20 MPG, the revenues from a VMT tax of \$0.0293 per mile are greater than the fuel taxes generated from a \$0.30 per gallon fuel tax. Thus, the basic vehicle revenues and equity share increase as shown in [Table 5](#).

**Table 4. Comparison of Revenue Shares and Equity Ratios for Basic Vehicle Registration Fee Case**

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratios	
	2011 Rates	Alt. Rates	2011 Rates	Alt. Rates
1 to 10,000	65.73%	66.85%	0.9954	1.0123
10,001 and up	34.27%	33.15%	1.0089	0.9761

**Table 5. Comparison of Revenue Shares and Equity Ratios for VMT Tax Case Study**

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratios	
	2011 Rates	Alt. Rates	2011 Rates	Alt. Rates
1 to 10,000	65.73%	75.88%	0.9954	1.1494
10,001 and up	34.27%	21.12%	1.0089	0.7098

# Appendix E: Model Documentation

## TABLE OF CONTENTS

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E15	Cost Allocation Methods
E17	Revenue Attribution Methods
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## MODEL OVERVIEW

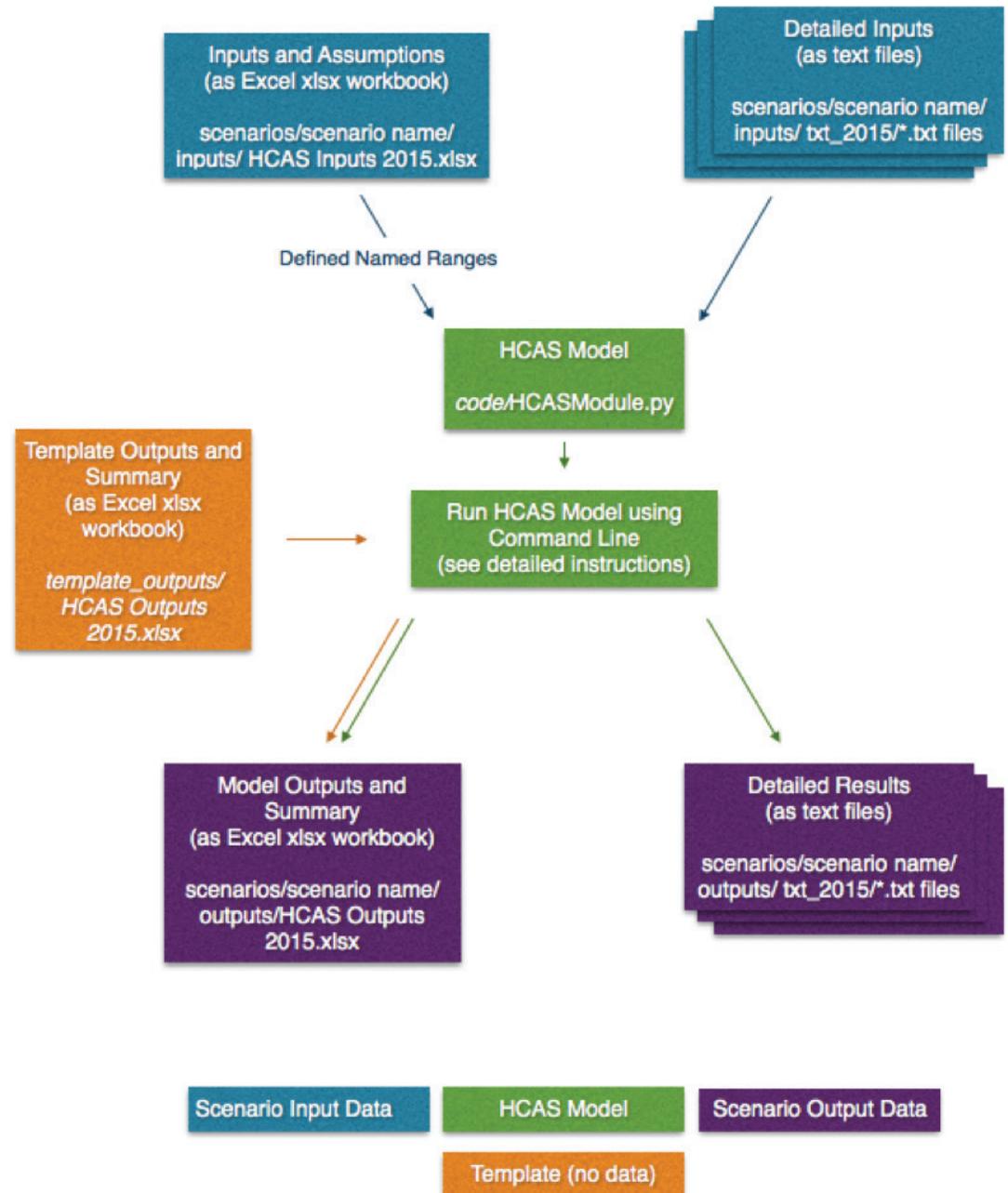
The full source code for the 2015 Oregon Highway Cost Allocation Model is included with the model distribution. The model is written in Python and is implemented by running `HCASModule.py`. The process for running the model is described in depth in [Appendix D, the Model User Guide](#). The 2015 model differs from prior Oregon HCASs where the model was run in an Excel workbook with a Visual Basic for Applications (VBA) routine that calls the Python code. The methods of the HCAS Python model that perform the actual calculations remain unchanged.

As described in the Model User Guide in [Appendix D](#), the user runs the 2015 HCAS Model with using a Graphic User Interface (GUI) in which the user can open and run the Python model. The HCAS Python code is centered on a class, `HCASModule`, that calls a series of methods when the Python file is executed.

This appendix provides a detailed description of each of the class methods that are called in the HCAS Python model, explaining the calculations and describing the internal data structures they use. [Figure 1](#) shows a graphical representation of the overall model process, including the Excel workbooks, the HCAS model, and the external data files. [Figure 1](#) shows the required inputs, templates and outputs of the model. Each box shows the general filepath from the base folder where the file(s) is located. Appendix D provides a detailed overview of how these files are setup and where they are located in the HCAS model folder.

[Table 1](#) describes the input ranges in various tabs of the “HCAS Inputs 2015.xlsx” workbook, listing the input range name, the tab it is located in, the data it contains, the units those data are in, the class method that loads the data into the HCAS model code, and the name of the data structure in the HCAS model code that accepts the data.

**Figure 1. Oregon Highway Cost Allocation Model**



**Table 1. Input Ranges**

Named Range	Tab	Model Function	Model Variable Name	Units	Contains
GrowthRates	VMT Growth	simpleSetup(xls_inputs['GrowthRates'])	self.growthRates	Annual growth rate (e.g., 0.05 means 5% per year)	VMT growth rates
VMTByFC	VMT by FC	simpleSetup(xls_inputs['VMTByFC'])	self.VMTbyFC	Base-year vehicle-miles traveled	VMT by functional class and ownership
BaseVMT	Base VMT	setBaseVMT(xls_inputs['BaseVMT'])	self.baseVMT	Base-year vehicle-miles traveled	Base-year VMT by weight class and tax class
Evasion	General	setEvasion(xls_inputs['Evasion'])	self.gasEvasion, self.dieselEvasion, self.wmtEvasion, self.basicDiesel, self.ruafRegRate, self.ruafReg78, self.ruafReg96, self.ruafReg104, self.emptyLogPercent, self.emptyLogWeight	All are shares (e.g., 0.05 means 5%) except RUAF Registration Rate is in dollars per mile traveled and Empty Log Weight is in pounds	Assumptions for gas-tax avoidance, use-fuel tax evasion & avoidance, weight-mile tax evasion, share of basic VMT that burn diesel, registration rate per mile for RUAF vehicles, share of RUAF vehicles registered at 78,001-80,000 lbs, share of RUAF vehicles registered at 96,001-98,000 lbs, share of RUAF vehicles registered at 104,001-105,500 lbs, percent of flat-fee log truck miles that are empty, declared weight for empty log trucks
Path	Policy	setPath(xls_inputs['Path'])	self.path	Names of allocators and shares	Allocator(s) to use for each work type
ProjectCosts	Project Costs	setProjectOrLocalCosts(xls_inputs['ProjectCosts'])	self.projectCosts	Biennial dollars	Costs to allocate for construction projects
NonProjectCosts	Non-Project Costs	setNonProjectOrStuddedTire(xls_inputs['NonProjectCosts'])	self.nonProjectCosts	Biennial dollars	Other costs to allocate
LocalCosts	Local Costs	setProjectOrLocalCosts(xls_inputs['LocalCosts'])	self.localCosts	Biennial dollars	Local-government costs to allocate
StuddedTire	General	setNonProjectOrStuddedTire(xls_inputs['StuddedTire'])	self.studdedTire	Biennial dollars	Studded-tire adjustments
BridgeFactors	General	setBridgeFactors(xls_inputs['BridgeFactors'])	self.bridgeFactors	Shares	Incremental factors for bridge work types
BondFactor	General	float(xls_inputs['BondFactor'])[0][0])	self.bondFactor	Share	Proportion of bonded expenditures to allocate in a biennium
Biennium	General	int(xls_inputs['Biennium'])[0][0])	self.biennium	Four-digit year	First year of model biennium
SWT	Codes	setSummaryTypesClasses(xls_inputs['SWT'])	self.summaryWorkTypes	Work type codes	Definitions of summary work types
SWC	Codes	setSummaryTypesClasses(xls_inputs['SWC'])	self.summaryWeightClasses	Pounds	Definitions of summary weight classes

**Table 2** describes the tab-delimited text files that contain input data for the HCAS model, listing the file name, what data it contains, the units those data are in, and the data structure in the HCAS model that accepts the data.

**Table 3** describes the outputs from the model code that populate the tabs in the “HCAS Outputs 2015.xlsx” workbook, listing the data structure in the HCAS model from which the data are extracted, the method called to calculate and retrieve the data, the tab into which the data are written, and the contents of the data.

**Table 4** describes the tab-delimited text files that are written when the HCAS model runs, listing the data structure in the HCAS model from which the data are extracted, the method called to calculate and write the data, the file names, and the contents of the data.

**Table 1 (continued). Input Ranges**

Named Range	Tab	Model Function	Model Variable Name	Units	Contains
RevenueTotals	Revenue Forecast	setRevenueTotals(xls_inputs['RevenueTotals'])	self.revenueTotals	Biennial dollars	Control totals for revenues by instrument
Rates	Rates	setRates(xls_inputs['Rates'])	self.rates	Dollars per whatever	Current-law rates except RUAF and flat fee
RUAFRates	Rates	setRUAFRates(xls_inputs['RUAFRates'])	self.RUAFRates	Dollars per mile	Current-law RUAF rates
FFRates	Rates	setFFRates(xls_inputs['FFRates'])	self.flatfee	Dollars per month, miles per month, and shares	Current-law flat fee rates
MPG	MPG		self.MPG	Miles per gallon	Assumed miles per gallon
AltRates	Alt Rates	setRates(xls_inputs['AltRates'])	self.altRates	Dollars per whatever	Alternative rates except RUAF and flat fee
AltRUAFRates	Alt Rates	setRUAFRates(xls_inputs['AltRUAFRates'])	self.altRUAFRates	Dollars per mile	Alternative RUAF rates
AltFFRates	Alt Rates	setFFRates(xls_inputs['AltFFRates'])	self.altFlatfee	Dollars per month, miles per month, and shares	Alternative flat fee rates

See: HCAS Inputs 2015.xlsx

**Table 2. Input Text Files**

File Name	Model Data Structure	Units	Contains
SeedData.txt	self.seedData	Unitless numbers	Used to populate a preliminary VMT Master table (VMTdata) for iterative proportional fitting (see below). Any seed values (except zeros) could be used to generate fitted results, but this particular set already contains data that reflect the relative proportions of different vehicle types on different functional classes, and so will produce a distribution that not only adds up to the correct totals for each weight class and each combination of functional class and ownership, but also reflects the fact that some functional classes carry higher proportions of heavy vehicles than others. There are five columns: facility class (combines functional class and ownership), functional class, ownership, weight class, axles, and VMT. The first four are keys.
AxleShares.txt	self.shares	Shares (e.g. 0.5 means 50%)	Contains the shares of vehicles weighing more than 105,500 pounds with each number of axles (5 to 9+) by weight class. These data are developed from Special Weighings data. There are three columns: weight class, axles, and share. The first two are keys
SimpleFactors.txt	self.simpleFactors	Shares	Contains vectors of factors to be multiplied by VMT for simple allocators (different weight groupings of VMT). These factors are mostly zeros and ones, reflecting the definition of the allocator. For example, the Under26 factor is one for all weight classes up to 26,000 pounds and zero for all weight classes over 26,000 pounds. There are ten columns: weight class, axles, AllVMT, BasicVMT, Over10VMT, Over26VMT, Over50VMT, Under26VMT, Over80VMT, Over106VMT, Snow, and AllAMT. The first two are keys; the rest are allocators.
PaveFactors.txt	self.paveFactors	Shares	Contains cost responsibility factors (by weight class, functional class, and number of axles) for wear and tear of flexible and rigid pavement projects. These factors are produced by the NAPHCAS-OR model (the Oregon version of the National Pavement Cost Model for Highway Cost Allocation developed by Roger Mingo). There are five columns: facility class (combines functional class and ownership), weight class, axles, flexible, and rigid. The first three are keys.
PCEFactors.txt	self.pceFactors	Shares	Contains passenger car equivalents (PCEs) by weight class, functional class, and number of axles for vehicles on regular, uphill, and congested roadways. These factors represent the amount of roadway capacity a single vehicle of a particular weight class takes up as a proportion of the capacity consumed by a basic vehicle. These factors were developed from a study conducted as a part of the 1997 federal highway cost allocation study. There are six columns: facility class (combines functional class and ownership), weight class, axles, regularPCE, UphillPCE, and congestedPCE. The first three are keys.
DeclaredRegistered.txt	self.declaredRegistered	Shares	Contains shares of vehicles in each declared weight class that are registered in each registered weight class. These data were developed from Motor Carrier registration data. There are three columns: declaredWeight, registeredWeight, and share. The first two are keys.
DeclaredOperating.txt	self.declaredOperating	Shares	Contains shares of vehicles in each declared weight class operating at each operating weight class. These data were developed from the Special Weighings data. There are five columns: declared, declaredAxles, operating, operatingAxles, and Share. The first four are keys.
BasicSharePeak.txt	self.peakShares	Shares	Contains the basic-vehicle share of peak-hour VMT for each functional class. These data were developed from automatic traffic recorder data. There are two columns: functionalClass and share. The first is the key.
BondsYYYY-YYYY.txt	self.priorBondAmount	Biennial dollars	Contains allocated bonded expenditures from prior studies. Uses such files, if they exist, from the nine most recent prior biennia. Columns are declared weight class, declared number of axles, and dollars. The first two are keys. Actual files will have biennium beginning and ending years in place of "YYYY".

**Table 3. Outputs**

Tab	Model Data Structure	Method to Create	Units	Contains
Model VMT	self.vmtByVehicles	makeVMTByVehicles()	Annual vehicle-miles traveled	Model year VMT by weight class and tax class
Allocated Costs	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Allocated costs by declared weight class, declared number of axles, and funding source
Allocated Costs by SWT	self.fullAllocatedCosts	getAllocatedCostsByWorkType()	Biennial dollars	Allocated costs by funding source, summary work type, and summary weight class
Costs to Allocate by SWT	self.projectCosts, self.nonProjectCosts, self.bondCosts, self.priorBondAmount	getCoststoAllocate()	Biennial dollars	Costs to allocate by funding source and summary work type
Attributed Revenues	attributedRevenues	attributeRevenues()	Biennial dollars	Attributed revenues by declared weight class, declared number of axles, and revenue instrument
Alt. Attributed Revenues	attributedRevenues	attributeAltRevenues()	Biennial dollars	Attributed alternative revenues by declared weight class, declared number of axles, and revenue instrument
MPG	self.adjustedMPG	getAdjustedMPG()	Miles per gallon	Calibrated estimates of miles per gallon by weight class

See: HCAS Outputs 2015.xlsx

**Table 4. Output Text Files**

File Name	Model Data Structure	Method to Create	Units	Contains
AllocatedCosts_bond.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from current and prior bonded expenditures. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_federal.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of federal funds by state government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_local-federal.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of federal funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_local-other.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of local funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.

**Table 4 (continued). Output Text Files**

File Name	Model Data Structure	Method to Create	Units	Contains
AllocatedCosts_local-state.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of state funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_other.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Not used. This may be ignored.
AllocatedCosts_state.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of state funds by state government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
BondsYYYY-YYYY.txt	allocatedBonds	allocateCosts()	Biennial dollars	Contains allocated bonded expenditures from this study. Will be used for the next nine biennia as an input file. Columns are declared weight class, declared number of axles, and dollars. The first two are keys. Actual file name will have beginning and ending years of the model biennium in place of "YYYY".
DeclaredPaveFactors.txt	self.pavement	makeVMTMaster()	Unitless factors	Contains pavement factors by facility class, declared weight class, and declared number of axles that are constructed from the raw pavement factors, which are by functional class, operating weight class, and actual number of axles. Columns are facility class, functional class, ownership, declared weight class, declared number of axles, flexible factor, and rigid factor. The first five are keys.
FlatFeeReport.txt	ffRevenue, asifWMTRevenue	allocateCosts()	Biennial dollars	Reports fees paid by flat-fee vehicles and the fees they would pay if they paid weight-mile tax. The 'as-if' revenue is to determine the flat fee difference. As of the 2011 study, flat-fee vehicles are not considered alternative fee-paying vehicles. Columns are declared weight class, declared number of axles, log revenue, as-if log revenue, dump revenue, as-if dump revenue, chip revenue, and as-if chip revenue. The first two are keys.
MissingPavementFactors.log	N/A	makeVMTMaster()	N/A	Lists any errors encountered while attempting to make pavement factors by facility class, declared weight class, and declared number of axles from raw pavement factors, which are by functional class, operating weight class, and actual number of axles.
VMTMaster.txt	self.VMTMaster	makeVMTMaster()	Annual vehicle-miles traveled	Contains annual VMT. Columns are functional class, ownership, declared weight class, declared number of axles, and vehicle-miles traveled. The first four are keys.
SubsidiesbyVehClass.txt	ffRevenue, regRevenue, ruafRevenue, wmtRevenue, gasTaxRevenue, dieselTaxRevenue, asifWMTRevenue	allocateCosts()	Biennial dollars	Contains calculated subsidies by subsidy type for WMT, Farm Registration, Tow Registration, Charitable Non-Profit Registration and E-Plate Registration for each weight class, and actual number of axles.

## DESCRIPTION OF MODEL CALCULATION OPERATIONS

The following describes what happens when the Python HCAS model, `HCASModule.py`, is run. [Figure 1 on page E3](#) illustrates the overarching process of the model. The model loads text files and tabs from the HCAS Inputs Excel workbook, performs calculations in Python, and then populates tabs with the results into the HCAS Outputs Excel workbook and saves output text files with detailed results.

### SEND BASE-YEAR VMT DATA AND RETRIEVE MODEL-YEAR VMT DATA

Growth rates, from the *VMT Growth* tab, tell the model how fast VMT in each weight class is expected to grow between the base year (the most recent calendar year for which data are available) and the model year (the calendar year in the middle of the fiscal biennium being modeled).

VMT by functional class, from the *VMT by FC* tab, provides control totals for base-year VMT in each functional class. Base VMT, from the *Base VMT* tab, provides base-year VMT by weight class and tax class.

Evasion rates, from the *General* tab, tell the model what evasion and avoidance rates to assume. Evasion and avoidance are combined.

The call to **`makeVMTMaster()`** tells the model to do its VMT calculations. The call to **`makeVMTByVehicles()`** tells the model to calculate model-year VMT by weight and tax class and populate the *Model VMT* tab in the outputs workbook.

### SEND COSTS TO ALLOCATE AND RETRIEVE ALLOCATED COSTS

The path, defined in the *Policy* tab, defines the set of allocators to be applied to each work type. Each work type may have up to two allocators. If there are two, the proportion of costs in that work type to which each will be applied is also defined in the path. The proportions must add up to one.

The model obtains costs to allocate from the *Project Costs*, *Non-Project Costs*, and *Local Costs* tabs. Items (rows) in the lists of costs to allocate include information about the funding source, work type, functional class, and dollar amount. Project costs also include the bridge type, which is zero if the project is not a bridge project.

The model obtains studded-tire adjustments from the *Studded Tires* table in the *General* tab. These move costs from their original combination of funding source and work type into the studded tire work type with the same funding source.

The model obtains bridge factors from the *Bridge Splits* table in the *General* tab. These factors are used to reassign bridge costs from their original work types to incremental cost work types so that incremental allocators may be applied. There will be a set of factors for each bridge type.

The model obtains the information necessary for the proper treatment of the expenditure of bond revenues from the *General* tab.

The *Codes* tab allows the model to tabulate allocated costs by summary work type and summary weight class for the report tables. These tabulations are done in the model, rather than in workbook, since it is faster, more reliable, and keeps the workbook size reasonable.

The `allocateCosts()` method allocates costs and returns the allocated costs by weight class and funding source, which then populate the *Allocated Costs* tab in the outputs workbook.

### SEND REVENUES AND RATES AND RETRIEVE ATTRIBUTED REVENUES

The model obtains revenue totals that are the control totals by instrument from the budget. Revenues are located in the *Revenue Forecast* tab in the inputs workbook. Rates are located in the *Rates* tab in the inputs workbook. Rates are for instruments that vary by weight class (e.g., weight-mile tax rates) or not at all (e.g., fuel taxes). The two other types of rates have different dimensions, so are sent separately. RUAF rates extend to a much longer list of weight classes. Flat-fee rates are by commodity and include information about the average miles per month for each weight class and the distribution of VMT in each weight class to numbers of axles for weights over 80,000 pounds. The model obtains estimated miles per gallon by operating weight class from the *MPG* tab in the inputs workbook.

The **`attributeRevenues()`** method attributes revenues and returns the attributed revenues by weight class and revenue instrument, which then populate the *Attributed Revenues* tab in the outputs workbook.

The call to **getAdjustedMPG()** tells the model to return the adjusted miles per gallon (already calculated as part of the revenue attribution calculations), which then populate the *MPG* tab of the outputs workbook to the right of the initial MPG estimates. The initial estimates are adjusted to allow fuel tax revenues to add up the revenue control totals for fuel taxes.

### RETRIEVE SUMMARY TABULATIONS FOR REPORT TABLES

The **getAllocatedCostsByWorkType()** method gets allocated costs by summary work type, funding source, and summary weight class, which then populate *Allocated Costs by SWT* tab in the outputs workbook.

The **getCostsToAllocate()** method returns costs to allocate by summary work type and funding source, which then populate the *Costs to Allocate by SWT* tab in the outputs workbook.

### SEND ALTERNATIVE RATES AND RETRIEVE ATTRIBUTED ALTERNATIVE REVENUES

The model obtains alternative rates from the *Alt Rates* tab. These alternative rates are used for policy analysis to test the effect on equity of proposed changes to revenue instruments. They do not require changes to revenue control totals, because they use the calibrated miles per gallon and miles per registration from the original revenue attribution calculations, which were calculated from the control totals and rates provided there.

The **attributeAltRevenues()** method attributes revenues using alternative rate schedules and returns results by weight class and revenue instrument, which populate the *Alt. Attributed Revenues* tab in the outputs workbook.

## DESCRIPTION OF MODEL CLASS METHODS

The following sections of the documentation serve two purposes: they describe in detail how the model does what it does and they provides a guide for following the source code. The class methods are described in the order they appear in the source code, which is the order in which they are called in running the model. The first section describes the class methods that load the input data into the model. The subsequent sections describe the way the model analyzes VMT, allocates costs, and attributes revenues. Line numbers from the version of the code included with the 2015 model distribution are included to facilitate following the source code.

## METHODS TO LOAD DATA

The class methods described in this section serve to get data into the HCAS model. Data that are not expected to be changed by the user are read in from tab-delimited text files. Data and assumptions that an analyst is more likely to want to change between model runs are loaded from the HCAS Inputs Excel workbook. Other class methods, described in later sections, make use of the data and return results to the HCAS Outputs Excel workbook and additional, more-detailed data to tab-delimited text files.

Note that variables beginning with “self.” belong to the class object and are available to any class method to which the self reference has been passed. Other variables are available only within the method that creates them.

### LOAD TEXT INPUT DATA

The **readData()** method (line 99) imports the following data sets from tab-delimited text files, which are expected to be in the inputs text folder:

- **AxleShares.txt** is read into self.shares and contains the shares of vehicles weighing more than 105,500 pounds by number of axles (5 to 9+) by weight class. These data are developed from Special Weighings data to describe the share of each weight class with each possible number of axles (nine or more axles are coded as nine-plus). There are three columns: weight class, axles, and share. The first two are keys.
- **BasicSharePeak.txt** is read into self.peakShares and contains the basic-vehicle share of peak-hour VMT for each functional class. These data were developed from automatic traffic recorder data. There are two columns: functionalClass and share. The first is the key.
- **DeclaredOperating.txt** is read into self.declaredOperating and contains shares of vehicles in each declared weight class operating at each operating weight class. These data were developed from the Weigh-in-Motion data. There are five columns: declared, declaredAxles, operating, operatingAxles, and share. The first four are keys.
- **DeclaredRegistered.txt** is read into self.declaredRegistered and contains shares of vehicles in each declared weight class that are registered in each registered weight class. These data were developed from Motor Carrier and DMV registration data. There are three columns: declaredWeight, registeredWeight, and share. The first two are keys.

- **PaveFactors.txt** is read into `self.paveFactors` and contains cost responsibility factors (by weight class, functional class, and number of axles) for wear and tear of flexible and rigid pavement projects. These factors are produced by the NAPHCAS-OR model (the Oregon version of the National Pavement Cost Model for Highway Cost Allocation developed by Roger Mingo). There are five columns: facility class (combines functional class and ownership), weight class, axles, flexible, and rigid. The first three are keys.
- **PCEFactors.txt** is read into `self.pceFactors` and contains passenger car equivalents (PCEs) by weight class, functional class, and number of axles for vehicles on regular, uphill, and congested roadways. These factors represent the amount of roadway capacity a single vehicle of a particular weight class takes up as a proportion of the capacity consumed by a basic vehicle. These factors were developed from a study conducted as a part of the 1997 Federal Highway Cost Allocation Study. There are six columns: facility class (combines functional class and ownership), weight class, axles, regularPCE, uphillPCE, and congestedPCE. The first three are keys.
- **SeedData.txt** is read into `self.seedData` and used to populate a preliminary VMT Master table (`VMTdata`) for iterative proportional fitting (see below). Any seed values (except zeros) could be used to generate fitted results, but this particular set already contains data that reflect the relative proportions of different vehicle types on different functional classes, and so will produce a distribution that not only adds up to the correct totals for each weight class and each combination of functional class and ownership, but also reflects the fact that some functional classes carry higher proportions of heavy vehicles than others. There are five columns: facility class (combines functional class and ownership), functional class, ownership, weight class, axles, and VMT. The first four are keys.
- **SimpleFactors.txt** is read into `self.simpleFactors` and contains vectors of factors to be multiplied by VMT for simple allocators (different weight groupings of VMT). These factors are mostly zeros and ones, reflecting the definition of the allocator. For example, the Under26 factor is one for all weight classes up to 26,000 pounds and zero for all weight classes over 26,000 pounds. There are twelve columns: weight class, axles,

AllVMT, BasicVMT, Over10VMT, Over26VMT, Over50VMT, Under26VMT, Over80VMT, Over106VMT, Snow, and AllAMT. The first two are keys; the rest are allocators.

## LOAD EXCEL INPUT DATA

Input data from the HCAS Inputs Excel workbook are loaded from the workbook using **loadExcellInputData()** method. This function takes the filename of the input workbook as an argument. In the 2015 HCAS, the model expects the HCAS Inputs Excel workbook to be in the inputs folder and have the filename 'HCAS Inputs 2015.xlsx'. A more detailed explanation of the inputs workbook setup is provided in Appendix D.

## Load Data for VMT Analysis

The following class methods process the loaded data for the VMT calculations. The HCAS model calls these methods to process data for the model before it calls the **makeVMTMaster()** method.

- **simpleSetup** (line 124) sets up data (in this case, `self.growthRates` and `self.VMTbyFC`) that has a shared format.

Captures VMT growth rates by weight class and puts them into `self.growthRates`. The key is weight class and values are annual growth rates for VMT.

Captures base-year VMT by functional class and ownership and puts them into `self.VMTbyFC`. The key is facility class (combination of functional class and ownership) and the values are base-year VMT. These data are developed from the state's HPMS submission and FHWA Highway Statistics reports.

- **setBaseVMT()** (line 131) captures base-year VMT by weight class and tax class and puts them into `self.baseVMT`. `self.baseVMT` is a nested dictionary. The outer keys are weight classes (from the first column of the second and greater rows of the input data). The inner keys are vehicle tax classes from the contents of the second and greater columns of the first row. Values are base-year VMT in that combination of weight class and tax class. These data are typically developed from a variety of sources, including the ODOT Revenue Forecast, DMV registrations data, Motor Carrier registrations data, weight-mile tax reports, flat-fee reports, and road-use assessment fee reports.

- **setEvasion()** (line 145) captures evasion and avoidance rates, along with some other assumptions used in revenue attribution. These assumptions are specified by the analyst. The function puts the assumptions into:
  - self.emptyLogWeight (the assumed declared weight of an empty log truck with its trailer decked)
  - self.emptyLogPercent (the assumed share of log-truck VMT that are driven while empty and with the trailer decked)
  - self.ruafReg104 (the assumed share of RUAF VMT by trucks with a registered weight of 104,001 to 105,500 pounds)
  - self.ruafReg96 (the assumed share of RUAF VMT by trucks with a registered weight of 96,001 to 98,000 pounds)
  - self.ruafReg78 (the assumed share of RUAF VMT by trucks with a registered weight of 78,001 to 80,000 pounds)
  - self.ruafRegRate (the assumed per-mile registration fee paid by trucks that pay the RUAF)
  - self.basicDiesel (the assumed proportion of basic VMT by diesel-powered cars and light trucks)
  - self.wmtEvasion (the assumed percent of total miles traveled by WMT vehicles upon which taxes are not paid)
  - self.dieselEvasion (the assumed percent of VMT by use-fuel-tax-paying vehicles for which the use-fuel tax was not paid; includes evasion and avoidance)
  - self.gasEvasion (the assumed percent of VMT by gas-tax-paying vehicles for which the gas tax was not paid; probably is entirely avoidance)

### Load Data for Cost Allocation

The following class methods capture data from the inputs workbook for the cost allocation calculations and are called before the model calls the **allocateCosts()** method.

- **setPath()** (line 160) captures allocation rules to be applied to each expenditure category (work type) and puts them into self.path. self.path is a nested dictionary. Outer keys are work-type codes and inner keys are allocator names. Values are shares of costs in that work type to which that allocator should be applied. These assumptions are specified by the analyst in conformance with the approach agreed upon by the Study Review Team.

- **setProjectOrLocalCosts()** (line 179) sets up data (e.g., self.projectCosts and self.localCosts) that has a shared format.

Captures project costs to be allocated and puts them into self.projectCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type. The values are biennial dollars of costs to allocate. These are typically derived from the ODOT Cash Flow Model and Project Control System.

Captures local government costs to be allocated and puts them into self.localCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type. The values are biennial dollars of costs to allocate. These are typically derived primarily from Local Roads and Streets Survey reports.

- **setNonProjectOrStuddedTire()** (line 188) sets up data (e.g., self.nonProjectCosts and self.studdedTire) that has a shared format.

Captures non-project costs to be allocated and puts them into self.nonProjectCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type (always zero). The values are biennial dollars of costs to allocate. These are typically derived from the Agency Request Budget.

Captures studded tire costs to be allocated and puts them into self.studdedTire. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type (always zero). The values are biennial dollars of costs to allocate, which will later be moved from the work types specified here into the work type for studded tire damage. These assumptions are supplied by the analyst.

- **setBridgeFactors()** (line 170) captures cost shares used to distribute bridge expenditures for incremental cost allocation and puts them into self.bridgeFactors, a nested dictionary. The outer key is the bridge type and the inner key is a bridge-reclassification work type. Values are shares of costs for that bridge type to be allocated according to that work type. Shares for each bridge type must add up to one. The default values for these assumptions were developed from the 2002 OBEC Bridge Cost Allocation Study.

- **self.bondFactor** (line 303) is defined as the proportion of bond-funded expenditures that will be repaid in a single biennium. This assumption is specified by the analyst. It represents the biennial repayment amount as a proportion of the principal amount.
- **self.biennium** (line 306) is defined as the starting year of the model biennium. Specified by the analyst.

### Load Data for Revenue Attribution

The following class methods capture data from the inputs workbook for the revenue attribution calculations. The HCASModule calls these methods to give data to the model before calling the standard implementation **attributeRevenues()** method or the alternative implementation **attributeAltRevenues()** method. The alternative rates are specified by the analyst to test changes in policy.

- **setRevenueTotals()** (line 198) captures revenue control totals and puts them into `self.revenueTotals`. The key is the name of the revenue instrument and the value is biennial dollars of revenue to attribute. These are typically derived from the Agency Request Budget and must be consistent with current-law rates and the VMT data and assumptions specified elsewhere.
- **simpleSetup** (line 124) sets up data (in this case, `self.MPG`) that has a shared format.
- Captures initial MPG assumptions by weight class and puts them into `self.MPG`. The key is operating weight class and values are miles per gallon. The default values for these assumptions were derived from a regression analysis of Vehicle Inventory and Use Statistics (VIUS) data.
- **setRates()** (line 208) captures current-law (or alternative) rates for each of gas tax, use-fuel tax, VMT tax, weight mile tax, normal registration, farm registration, tow registration, charitable/nonprofit registration, e-plate registration, light-trailer registration, heavy-trailer registration, and title fees and puts them into `self.rates` (or `self.altRates`). `self.rates` (or `self.altRates`) is a nested dictionary. The outer keys are revenue instruments and the inner keys are tuples of weight class and number of axles. Values are rates in dollars per VMT, gallon, or year, as appropriate. For the standard implementation, these are specified by the analyst based on current law and must match the assumptions used to develop the

revenue control totals. For the alternative implementation, these are specified by the analyst to test proposed changes to rates.

- **setRUAFRates()** (line 220) captures current-law (or alternative) road-use assessment fee rates and puts them into `self.RUAFRates` (or `self.altRUAFRates`). The key is a tuple consisting of weight class and number of axles and values are dollars per mile. For the standard implementation, these are specified by the analyst based on current law. For the alternative implementation, these are specified by the analyst to test proposed changes to rates.
- **setFFRates()** (line 227) captures current-law (or alternative) monthly flat-fee rates, average monthly miles, and axle distribution and puts them into `self.flatfee` (or `altFlatfee`). The key is one of 'Log Rate', 'Dump Rate', 'Chip Rate', 'Log VMT', 'Dump VMT', 'Chip VMT', 'Log Axles', 'Dump Axles', or 'Chip Axles' and the values are rates in dollars per month, average miles per month, or shares of VMT in that weight class accounted for by trucks with that number of axles, as appropriate. For the standard implementation, rates are specified by the analyst based on current law and the assumptions about average miles per month and distribution of miles among numbers of axles are derived from flat-fee reports from MCTD. For the alternative implementation, rates are specified by the analyst to test proposed changes to rates.

### Load Data for Summary Tables

The following class methods capture data from the inputs workbook and use it to tabulate summary tables of allocated costs and costs to allocate. The HCASModule calls these methods to give data to the model before calling the **getAllocatedCostsByWorkType()** and **getCostsToAllocate()** methods.

- **setSummaryTypesClasses()** (line 240)
  - Captures definitions of summary work types and puts them into `self.summaryWorkTypes`. The key is the work type and the value is the summary work type.
  - Captures definitions of summary weight classes and puts them into `self.summaryWeightClasses`. The key is the weight class and the value is the summary weight class.

## VMT ANALYSIS METHODS

The **makeVMTMaster()** method (line 434) returns VMT by functional class, ownership, weight class, and number of axles for the model year. It uses VMT by weight class and number of axles (VCTotals, obtained from self.baseVMT), VMT by functional class and ownership (FCTotals, obtained from self.VMTbyFC), and the seed data from self.seedData to create a VMT Master table.

Using iterative proportional fitting, the program repeatedly scales the seed data until each row sums to its corresponding VC total and each column sums to its corresponding FC total. The program stops fitting data once the sum of squared errors for the fitted values falls below a specified threshold.

### METHODS WITHIN MAKEVMTMASTER()

The following methods are defined and used within the **makeVMTMaster()** class method:

- **findFCSums()** (line 449) sums VMTData by functional class and ownership across weight classes and numbers of axles.
- **findVCSums()** (line 457) sums VMTData by weight class and number of axles across functional class and ownership.
- **scaleToFC()** (line 465) multiplies each value in VMTData by the ratio of its FCTotal control total to its current FCSum.
- **scaleToVC()** (line 472) multiplies each value in the VMTData by the ratio of its VCTotal control total to its current VCSum.
- **findSSE()** (line 479) calculates the sum of squared errors for the FCSums. (The SSE for VCSums will equal zero because the scaling process for VCSums runs after scaling for FCSums.) The “errors” are differences between the sums of VMT by individual facility class and the control total for that facility class. They are squared (multiplied by themselves) before adding up over facility classes for two reasons: positive and negative differences can’t cancel each other out and a large difference in an individual facility class will be given greater weight than several small differences that add up to the large difference. It is important that none be off by a lot, but it is acceptable for many to be off by a tiny amount each.

### HOW MAKEVMTMASTER() WORKS

VMTMaster is a matrix of vehicle-miles traveled (VMT) by vehicle classes and by road classes. Vehicle classes are combinations of 2,000-pound weight increments and numbers of axles. Road classes are combinations of functional classes (defined by the Federal Highway Administration) and ownership.

We start with base-year VMT by declared weight class by tax class to develop the row totals. Vehicles weighing 80,000 pounds and under are not classified by axles (axles=0). Base-year VMT by weight-mile-tax vehicles between 80,000 and 105,500 pounds are available by numbers of axles because the tax rate varies with the number of axles. Other vehicles in this range (e.g., farm, publicly-owned, or road-use assessment fee) are assumed to have the same distribution of miles by number of axles within each weight class as weight-mile tax vehicles.

Base-year VMT by road-use-assessment-fee vehicles weighing more than 105,500 pounds are distributed among numbers of axles according to the proportions specified in self.axleShares. A dictionary named VCTotals, keyed by weight class and number of axles, is built to contain the row totals for the VMT Master matrix.

The column totals are copied from self.VMTbyFC and scaled to add up to exactly the same total as the row totals. The individual cells of the VMT Master matrix are initialized with the proportions from self.seedData. The columns initially sum to one.

The iterative proportional fitting follows the following steps:

1. Scale each column so that it adds up to its column control total (scaleToFC())
2. Sum each row (findVCSums())
3. Scale each row so that it adds up to its row control total (scaleToVC())
4. Sum each column (findFCSums())
5. Find the sum of squared differences between column totals and column control totals and compare to the threshold value (findSSE()). The threshold value is arbitrarily set to 48, meaning that if each of the 48 facility classes was off by less than one vehicle mile traveled (out of a total of more than 30 billion), it would be satisfied.
6. If the sum of squared errors is less than the threshold, stop. Otherwise, return to Step 1.

Once iterative proportional fitting is complete, the growth rates for each weight class from `self.growthRates` are applied to the fitted base-year VMT data to bring it to the model year (the middle 12 months of the study biennium).

Three additional, summary facility classes are then added to the matrix. FC 0 is all state-owned roads, FC -1 is all roads, and FC -2 is all locally owned roads.

VMTMaster is copied to `self.VMTMaster` for use by other methods, is written to disk, and selected portions (FC -2 to FC 0, and all combinations of state ownership and functional class) are returned to the *Model VMT* tab in the outputs workbook.

The key in `self.VMTMaster` is a tuple consisting of facility class, declared weight class, and declared number of axles. Values are model-year VMT.

Once VMTMaster is built, it is used to convert `self.paveFactors`, which are by operating weight, actual number of axles, and functional class, into factors by declared weight class, declared number of axles (zero if declared weight under 80,000 pounds and nine if nine or more), and facility class (combinations of functional class and ownership, including the aggregate facility classes for all roads, all state-owned roads, and all locally owned roads), which are stored in `self.pavement` and used in `allocateCosts()` to allocate pavement costs to declared weight classes. The factors in `self.pavement` are VMT-weighted averages of the factors in `self.paveFactors`. Factors are constructed for both flexible and rigid pavements.

The structure of `self.pavement` is a nested dictionary. The outer key is the pavement type (Flex or Rigid) and the inner key is a tuple consisting of facility class, declared weight class, and declared number of axles. The code for preparing the pavement factors is intermingled with the code for building VMTMaster to save repeated looping over the same data structures.

The `makeVMTByVehicles()` method (line 658) multiplies VMT values in `self.baseVMT` by the appropriate compounded growth rates to produce `self.vmtByVehicles`, which contains model-year VMT by weight class and tax class. These are returned to the HCAS Outputs workbook. `self.vmtByVehicles` is a nested dictionary. The outer key is the tax class and the inner key is the weight class.

## COST ALLOCATION METHODS

The `allocateCosts()` method (line 686) performs the following processes:

- Combine local costs data from `self.localCosts` with project costs data from `self.projectCosts` into `self.projectCosts` (line 690).
- Do bridge splits on project costs (line 694). For projects in work types 13, 14, 15, 19, 67, 68, 113, 114, 115, 119, 167, and 168 (bridge and interchange projects), the bridge type for each project is identified and the project's cost is split into multiple work types (60-65) using the bridge factors appropriate to the bridge type. Costs in the original work types are removed from `self.projectCosts` and the aggregated, split costs in work types 60-65 are inserted into `self.projectCosts`. Bridge projects that add capacity (work types 67, 68, 167, and 168) get their base increment allocated according to the allocator(s) specified in work type 65, so the portion of their costs that would go to work type 60 according to the bridge factors defined in the Bridge Splits tab of the workbook is instead assigned to work type 65.
- Separate bond projects and apply the bond factor (line 709). Projects where the funding source is "bond" are identified, their costs are multiplied by the bond factor, and they are removed from `self.projectCosts` and inserted into `bondsToAllocate`.
- Do studded tire adjustment (line 716). For each work type and corresponding dollar amount in `self.studdedTire`, the dollar amount is divided proportionally among all projects in that work type in `self.projectCosts` and moved out of those projects and into work type 39 or 139 (if the original work type was over 100, indicating work on locally owned roads).
- Set up allocation vector data structure (allocators) and build allocation vectors (line 739). There are allocation vectors for each combination of allocator, functional class, and ownership. Within each allocation vector, there is an element for each combination of weight class and number of axles.
- Build allocation vectors with the vector of allocation factors appropriate to the allocator. The allocation factors are proportional to costs imposed per VMT and come from `self.simpleFactors`, `self.pavement`, and `self.pceFactors`. Each allocation factor is then multiplied by the VMT in that

combination of weight class and number of axles for the combination of functional class and ownership for which the allocation vector is being prepared, which come from self.VMTMaster. The VMT multiplied by the allocation factors for Congested PCE are adjusted using the shares from self.peakShares so that they represent VMT during the peak hour for that functional class.

- Scale allocation vectors so that the elements of each vector sum to one (line 793). The resulting allocation vectors may then be multiplied by a project cost and the result will be a vector of allocated costs with each element containing the dollar amount for that combination of weight class and number of axles. All the elements in the allocated costs vector sum to the original amount to be allocated. For this to work, it is necessary that there be non-zero VMT in the combination of functional class and ownership associated with the project. Incorrectly recorded functional classes (e.g., locally owned interstates) can cause costs to disappear during allocation.
- Apply allocation vectors to project costs to allocate (except for “other construction” and “other bridge” costs) as described above to generate allocated project costs (line 800).
- Make Other Bridge and Other Construction allocators (line 814). Once bridge project costs other than “other bridge” have been allocated, a special allocation vector is built to allocate these costs in proportion to all previously allocated bridge project costs. The same is done to create a special allocation vector to allocate “other construction” costs in proportion to all previously allocated construction project costs.
- Apply Other Bridge and Other Construction allocators to “other bridge” and “other construction” costs (line 858).
- Apply allocators to non-project costs (line 872). Any bond-funded projects found in self.nonProjectCosts are removed, multiplied by self.bondFactor, and added to bondsToAllocate. Remaining non-project costs have the appropriate allocation factors applied to them and are added to allocatedCosts.
- Apply allocation vectors to bonded costs to allocate (line 894). Applies the allocators to bondstoAllocate and stores the result in allocatedBonds.

- Store allocated bonded costs (line 909). Creates a text file of allocated bond costs (allocatedBonds) for use in future studies. (Future model runs will use this file to obtain prior allocated bond costs.)
- Get prior allocated bonds from files (line 925). Captures allocated, current payments due on bonds issued for projects in previous biennia (priorBonds).
- Add current and prior allocated bonded costs to allocatedCosts (line 947).
- Write out detailed allocation results to tab-delimited text files, one for each funding source (line 959). These are named AllocatedCosts\_federal.txt, AllocatedCosts\_state.txt, etc.
- Copy allocators to self.allocators and allocatedCosts to self.fullAllocatedCosts (line 974).
- Prepare a summary table of allocated costs and that is returned to the HCAS Outputs workbook (line 978). Columns are funding sources and rows are combinations of declared weight class and declared number of axles. Cells contain allocated biennial dollars.

The **getAllocationVectors()** method (line 999) gets the allocation vectors from self.allocators. Columns are allocators and rows are combinations of facility class, declared weight class, and declared number of axles.

The **getAllocatedCostsByWorkType()** method (line 1030) gets allocated costs from self.fullAllocatedCosts and aggregates them by summary work type from self.summaryWorkTypes and by summary weight class from self.summaryWeightClasses and returns the aggregated allocated costs to the *Allocated Costs by SWT* tab in the outputs workbook. Columns are summary weight classes and rows are combinations of funding source and summary work type. Cells contain allocated biennial dollars.

The **getCostsToAllocate()** method (line 1066) gets costs to allocate from self.projectCosts (which now includes local costs and excludes bonded costs), self.nonProjectCosts (which now excludes bonded costs), self.bondCosts, and self.priorBondAmount and aggregates them by summary work type from self.summaryWorkTypes. It returns the aggregated costs to allocate to *Costs to Allocate* tab in the outputs workbook. Note that prior bond amounts do not contain information about their original work type

and are put into their own summary work type (21). Columns are funding sources and rows are summary work types. Cells contain biennial dollars.

## REVENUE ATTRIBUTION METHODS

The **attributeRevenue()** method (line 1103) performs the following processes:

- Attribute road-use assessment fee (RUAFF) revenue (line 1105). RUAFF revenues are attributed to weight classes by multiplying their model-year VMT in each combination of weight class and number of axles by the appropriate RUAFF rate from self.RUAFFRates. RUAFF VMT are the total VMT in that combination of weight class and number of axles from self.VMTMaster times the ratio of RUAFF VMT in that weight class to all VMT in that weight class from self.vmtByVehicles. This assumes that axle shares for RUAFF vehicles under 105,500 pounds will be the same as for weight-mile tax vehicles in the same weight class, which has been determined to be a reasonable assumption. The resulting revenues are doubled to make them biennial. It is assumed that there is no evasion of road-use assessment fees. Attributed RUAFF revenues are put into ruafRevenue, where the key is a tuple consisting of weight class and number of axles and the value is biennial dollars.
- Attribute weight-mile tax (WMT) revenue and as-if WMT revenue (line 1117). WMT revenues are attributed to weight classes by multiplying their model-year VMT in each combination of weight class and number of axles from self.vmtByVehicles by the appropriate WMT rate from self.rates. The base-year VMT from which the model-year VMT were derived were adjusted upward from base-year WMT reports to account for assumed evasion, so the reverse adjustment must be applied to estimate WMT revenue. This is accomplished by multiplying revenues by (1.0 - self.wmtEvasion). The resulting revenues are doubled to make them biennial and stored in wmtRevenue. For all VMT by vehicles in weight classes to which WMT rates apply, but do not pay the WMT, flat fee, or RUAFF, the weight-mile taxes they would pay if they did pay the WMT are calculated and stored in asifWmtRevenue. As-if WMT revenues for those paying flat fees are calculated later, along with flat-fee revenues. The key in both wmtRevenue and asifWmtRevenue is a tuple consisting of declared weight class and declared axles.
- Attribute flat-fee revenue (line 1145). For each flat-fee commodity (log, dump, and chip), for each combination of weight class and number of axles, divide the model-year VMT by the average VMT per month for that commodity and weight, and multiply the resulting number of vehicle-months by the appropriate monthly flat-fee rate. As-if weight-mile taxes for flat-fee-paying vehicles are calculated at the same time. For flat-fee log trucks, the model VMT must be adjusted prior to estimating as-if WMT revenues. When paying the WMT, log trucks can declare a lower weight when empty and traveling with their trailer decked. When estimating as-if WMT revenues for flat-fee log trucks, VMT in each weight class are multiplied by (1.0 - self.emptyLogPercent) and then by the WMT rate appropriate to that weight class. The VMT then are multiplied by self.emptyLogPercent and the WMT rate appropriate to self.emptyLogWeight. The flat-fee and as-if WMT revenues are doubled to make them biennial and stored in ffRevenue and asifWmtRevenue, respectively. A tab-delimited text file, FlatFeeReport.txt, containing flat-fee VMT, revenues, and as-if WMT revenues by commodity and weight class is written out to disk as a text file.
- Attribute registration and title revenues (line 1173). Budgeted total DMV registration, Motor Carrier Apportioned, Motor Carrier Non-Apportioned, and title fee revenues are attributed to vehicle classes using fee-weighted VMT. VMT for vehicles over 26,000 pounds are adjusted using the declared-to-registered factors. VMT by tax class and weight class are multiplied by the registration fee that applies to that combination and the resulting amounts are scaled so that they add up to the total expected registration fee revenue. For vehicles over 26,000 pounds, registration fee revenues by registered weight are converted back to revenues by declared weight class using the same declared-to-registered factors. A further adjustment is made to give RUAFF vehicles credit for the registration fees they pay.
- This method eliminates the need for forecasting vehicle counts and automatically accounts for the substantial registration revenues that are produced by fees other than the regular registration fee (e.g., temporary registrations, duplicates, etc.). It also eliminates the need for directly forecasting the number of titles that will be issued. There is an implicit assumption that vehicles in the different weight classes of heavy vehicles all travel the same number of miles per title issuance. "As-if"

registration fees are estimated for alternative-fee-paying vehicles. As of the 2011 Study, Flat Fee vehicles are no longer treated as alternative fee-paying vehicles.

- The method loops over the rows (combinations of declared weight class and declared number of axles) in self.rates, which are the current-law rates entered in the General tab of the HCAS Inputs workbook. It multiplies the fee per year by the VMT per year by the vehicles subject to that fee (as if the rate were per VMT). It then adds up those (large) numbers for each instrument and divides the biennial revenue control total for that instrument by the sum of annual miles times annual fee for that instrument. It applies that ratio to the annual miles times annual fee for each combination of declared weight class and declared number of axles to get biennial revenues for that combination and instrument.
- For vehicles over 26,000 pounds, an individual vehicle will have one registered weight, but may have multiple declared weights, depending on configuration. When getting the annual VMT to multiply by each rate, self.declaredRegistered, which contains the proportion of VMT for each declared weight class that is in each registered weight class, is used.
- For vehicles over 80,000 pounds, the revenues are attributed to vehicle classes defined by both declared weight and number of axles, so axle shares for each weight class are calculated and used to spread the registration revenues (which vary only with weight) among the numbers of axles for each weight class.
- At the same time that registration revenues are attributed for “alternative” registration fees (e.g., farm, charitable/non-profit, publicly owned, etc.), “as-if” registration fees are calculated as if they paid the “normal” registration rate for their weight. Those are used later to calculate the “subsidy” amount.
- Make an adjustment to registration revenues to give RUAF vehicles some credit (line 1329). When a vehicle pays the road-use assessment fee, it is often operating at a weight above the maximum allowed declared or registered weight of 105,500 pounds. These vehicles do pay registration fees, but at a weight that does not correspond to the weight recorded in the RUAF data. Assumptions are specified in the Revenues tab of the workbook that allow RUAF vehicles to be credited with registration fees by transferring attributed fees from lower weight classes.
- Attribute fuel tax and VMT tax revenues (line 1350). Gasoline and diesel fuel tax revenues are attributed separately because the model allows for different tax rates and different evasion/avoidance assumptions. VMT by fuel type and weight class for fuel-tax paying vehicles are assembled and adjusted for evasion/avoidance. A preliminary attribution is made by dividing the adjusted VMT in each combination of weight class and fuel type by the assumed miles per gallon for that weight class from the MPG data set and multiplying the resulting number of gallons by the per-gallon rate for that fuel type. The attribution to vehicles between 10,001 and 26,000 pounds is then adjusted to bring those weight classes, as a group, to equity (before considering subsidies). The attribution to basic vehicles (those 10,000 pounds and under) is adjusted to make the total revenues attributed add up to the forecast revenues from the budget. The implied miles per gallon after adjustment for each weight class is calculated and returned to the *MPG* tab in the outputs workbook where it may be examined for reasonableness. The reasons for using this approach are detailed in Issue Paper 6 from the 2005 study.
- The first step in attributing fuel tax revenues is finding the taxed VMT by weight class for the gas tax and for the use-fuel (diesel, etc.) tax, taking into account avoidance, evasion, the portion of basic vehicles that do not burn gasoline, and the fact that publicly owned vehicles such as transit and school buses do not have to pay the use-fuel tax.
- The taxed VMT for each weight class is divided by the assumed miles per gallon from self.MPG and multiplied by the tax rate per gallon to get revenues by weight class. The assumed miles per gallon for vehicles between 10,001 and 26,000 pounds are then adjusted to force those weight classes into perfect equity (before the subsidy adjustment) and their attributed fuel-tax revenues are recalculated. The sum of attributed non-basic (over 10,001 pounds) fuel taxes are subtracted from their revenue control totals, leaving the amount from basic vehicles. The assumed average basic-vehicle is then recalculated so that basic vehicles will produce this amount of revenue and that amount is attributed to basic vehicles. The calibrated miles-per-gallon assumptions are stored in self.adjustedMPG.
- Attribute other motor carrier revenue (line 1455). Budgeted other motor carrier revenue is attributed to heavy vehicle weight classes on the basis of all RUAF and WMT VMT.

- Determine subsidy amount for each weight class (line 1488). These are calculated for each tax class by subtracting what they do pay in each revenue category from what they would pay if they paid the “regular” tax or fee. Subsidy amounts may be negative.
- Prepare a table of attributed revenues and subsidy amounts to save to a tab in the outputs workbook (line 1522).

Attributed revenues are saved in the *Attributed Revenues* tab of the outputs workbook. **getAdjustedMPG()** (line 1534) returns the calibrated miles-per-gallon assumptions from self.adjustedMPG to the *MPG* tab in the outputs workbook.

## ALTERNATIVE REVENUE ATTRIBUTION METHODS

The **attributeAltRevenues()** (line 1550) method repeats the revenue attribution process using alternative rates specified by the analyst in the *Alt. Rates* tab of the inputs workbook.

The process for alternative revenue attribution is essentially the same as for the primary revenue attribution, but there are important differences:

- When attributing registration and title fee revenues, assume that the revenues per VMT for each combination of instrument and weight class will change by the ratio of alternative rate to original rate. This allows estimating revenues from alternative registration and title fees without specifying the total revenue they will produce in advance.
- When attributing fuel-tax revenues, use the calibrated miles per gallon from the original revenue attribution. This allows estimating revenues from alternative fuel-tax rates without specifying the total revenue they will produce in advance.

Alternate attributed revenues are saved in the *Alt. Attributed Revenues* tab of the outputs workbook.

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# Appendix F: Model Input Tables

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F3 Model Assumptions and Data Sources

## MODEL ASSUMPTIONS AND DATA SOURCES

This appendix documents the assumptions and data used in the final run of the HCAS model for the 2015 Highway Cost Allocation Study. Data used in the final model run were collected between roughly June 2013 and January 2015. The final model run was completed and verified in March 2015.

Table 1 through Table 6 list assumptions in the HCAS Inputs Excel workbook that are used in the final run of the model. Table 1 and Table 2 have the HCAS Inputs workbook tab listed in the first column followed by the assumption name or brief description.

Like prior HCAS inputs workbooks, this workbook includes a *Base VMT* tab. Table 1 lists the assumptions used to develop the *Base VMT* tab in the 2015 inputs workbook. These assumptions are yellow-shaded cells in their respective workbook tabs. The key tabs that are linked to and build up the *Base VMT* tab are the *VMT Growth*, *DMV VMT*, *MCTD VMT*, *Federal VMT*, and *Bus VMT* tabs. This setup of the *Base VMT* tab differs from prior HCASs. In prior HCASs, the data in the *Base VMT* tab in the HCAS Inputs Excel workbook were built up in a separate “Base VMT.xlsx” workbook.

Table 2 lists the assumptions in the HCAS inputs workbook. Most of the assumptions listed in Table 2 correspond to yellow-shaded cells in their respective workbook tab.

Table 3 through Table 6 display the assumptions for studded tires, motor home weight classes, bridge splits, and initial mpg because these assumptions are tables or ranges, not single values.

Table 3 displays expenditures related to studded tires. It shows biennium expenditures by funding source, work type and facility class.

Table 4 displays the assumed weight classes by motor home length used to assign motor home VMT to weight classes in the *DMV VMT* tab in the HCAS Inputs workbook.

Table 5 displays the assumed bridge splits used to split bridge project expenditures among the bridge reclassification work types. These assumed values are from the 2002 OBEC Bridge Allocation Report.

Table 6 contains the assumed initial MPG, created from regression of the 2002 Vehicle Inventory and User Survey published by the U.S. Census Bureau. The Vehicle Inventory and Use Survey was discontinued after 2002.

Table 7 lists the files and sources of the data used in the 2015 Final HCAS model run.

**Table 1. Base VMT Worksheet Assumptions**

Tab	Assumption	Value
DMV VMT	Commercial Trucks & Buses Annual VMT per vehicle (10,001 to 26,000 weight class)	19,000
DMV VMT	Tow Truck Annual VMT per vehicle	15,000
DMV VMT	Farm Vehicle Annual VMT per vehicle (by weight class)	
	<i>less than 20,001 lbs</i>	3,000
	<i>20,001 to 40,000 lbs</i>	3,500
	<i>40,001 to 50,000 lbs</i>	4,000
	<i>50,001 to 70,000 lbs</i>	4,500
	<i>70,001 to 80,000 lbs</i>	5,000
	<i>80,001 to 90,000 lbs</i>	6,000
	<i>90,001 to 100,000 lbs</i>	7,000
	<i>100,001 to 104,000 lbs</i>	7,500
	<i>104,001 lbs and up</i>	8,000
DMV VMT	State & Local Annual VMT per vehicle (by weight class)	
	<i>less than 20,001 lbs</i>	13,000
	<i>10,001 to 26,000 lbs</i>	12,000
	<i>26,001 lbs and up</i>	11,000
DMV VMT	Charitable & Non-Profit Annual VMT per vehicle	10,000
DMV VMT	Motorhome Annual VMT per vehicle	3,988
DMV VMT	Motorhome length/weight class assumptions (from Winnebago vehicle spec. information)	See Table 4

See: *DMV VMT* tab, HCAS Inputs 2015.xlsx

**Table 2. HCAS Model User-Specified Assumptions**

Tab	Assumption	Value	Justification/Source
General	Split of bridge expenditures across bridge reclassification work types	See <a href="#">Table 5</a>	2002 OBEC Bridge Allocation Study
General	Base Year	2013	Ch. 2, pg. 9
General	Biennium	2015	Ch. 2, pg. 9
General	BondFactor	0.1605	Ch. 3, pgs. 21-22
General	Forecast Year (also, Model Year)	2016	Ch. 2, pg. 9
General	Percent of basic gallons that are diesel	5%	NA
General	Percent of RV gallons that are diesel	40%	NA
General	Percent of taxed gallons that are basic	94%	NA
MPG	MPG (initial) by weight class	See <a href="#">Table 6</a>	Regression on 2002 VIUS data
Policy	Preliminary and Construction Engineering (and etc.) Share 1	55.95%	Ch. 3, pg. 17
Policy	Right of Way (and Utilities) Share 1	73.75%	Ch. 3, pg. 17
Policy	New Pavements-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	New Pavements-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Rehab-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Rehab-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Surface and Shoulder Maintenance-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Surface and Shoulder Maintenance-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Local Gov: Preliminary and Construction Engineering (and etc.) Share 1	55.92%	Ch. 3, pg. 19
Policy	Local Gov: Right of Way (and Utilities) Share 1	55.92%	Ch. 3, pg. 19
Policy	Local Gov: New Pavements-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: New Pavements-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Rehab-Flexible Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Rehab-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Surface and Shoulder-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Surface and Shoulder-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	All other Allocators Shares for work types not PE, ROW, or Pavement	100%	Ch. 3, pgs. 17-20
General	Gas Tax Avoidance Rate	3.53%	Ch. 3, pg. 23

**Table 2 (continued). HCAS Model User-Specified Assumptions**

Tab	Assumption	Value	Justification/Source
General	Diesel Tax Evasion & Avoidance Rate	4.53%	Ch. 3, pg. 23
General	WMT Evasion Rate	5%	Ch. 3, pg. 23
General	Basic Diesel (percent of basic VMT by diesel vehicles)	5%	
General	Taxed Diesel (percent of taxed gallons that are diesel)	9.47%	
General	RUAF Registration Adjustment	4.5%	NA
General	RUAF Reg. from 78001	14%	NA
General	RUAF Reg. from 96001	15%	NA
General	RUAF Reg. from 104001	71%	NA
General	Log truck miles empty	50%	Ch. 7, pg. 63
General	Empty log truck declared weight (lbs)	42,001	Ch. 7, pg. 63
General	E-Plate Registration, annualized	40%	One-time registration fee of \$2 divided by 5 yrs.
General	Split of studded tire expenditures across funding sources and work types	See <a href="#">Table 3</a>	NA
General	State/Local-State split (speed adjustment factor)	11%	NA
General	Preservation costs inflation rate	3%	NA

See: HCAS Report; *General, Policy* and *MPG* tabs, HCAS Inputs 2015.xlsx

**Table 3. Studded Tire Assumptions**

Funding	Work Type	Facility Class	Biennium Expenditures (\$)	Distribution by Work Type
state	-	0	8,570,779 <sup>1</sup>	100%
state	1	0	407,453	5%
state	11	0	6,790,885	79%
state	26	0	1,372,441	16%
local-state	-	-2	942,786 <sup>2</sup>	100%
local-state	101	-2	44,820	5%
local-state	111	-2	746,997	79%
local-state	126	-2	150,968	16%

See: *General* tab, HCAS Inputs 2015.xlsx

<sup>1</sup>Figure 5.5, Review of Studded Tires in Oregon, Final Report, SPR 304-671, December 20, 2014, ODOT Research Section

<sup>2</sup>Equal to 11% of state expenditures (using state / local-state split, speed adjustment factor).

**Table 4. Motorhome Length to Weight Class Assumptions**

Min. Length (feet)	Max. Length (feet)	Weight Class
0	22	1
23	24	10,001
25	26	12,001
27	30	14,001
31	32	16,001
33	34	18,001
35	35	22,001
36	36	24,001
37	37	26,001
38	38	28,001
39	50	30,001

See: *DMV VMT* tab (Motorhomes Table), HCAS Inputs 2015.xlsx

**Table 5. Bridge Split Assumptions**

Bridge Type	Work Type	Share
0	60	0.6849
0	61	0.2520
0	62	0.0000
0	63	0.0000
0	64	0.0631
1	60	0.6666
1	61	0.2999
1	62	0.0000
1	63	0.0000
1	64	0.0335
2	60	0.6849
2	61	0.2520
2	62	0.0000
2	63	0.0000
2	64	0.0631
3	60	0.7221
3	61	0.1697
3	62	0.0000
3	63	0.0514
3	64	0.0568
4	60	0.8713
4	61	0.1029
4	62	0.0000
4	63	0.0000
4	64	0.0258

See: *General* tab (Bridge Splits table), HCAS Inputs 2015.xls

**Table 6. MPG Assumptions (Initial MPG)**

Declared	MPG	Declared (cont.)	MPG (cont.)
1	20.00	110,001	5.07
10,001	10.85	112,001	5.04
12,001	10.27	114,001	5.01
14,001	9.77	116,001	4.99
16,001	9.33	118,001	4.96
18,001	8.94	120,001	4.93
20,001	8.59	122,001	4.91
22,001	8.27	124,001	4.88
24,001	7.98	126,001	4.86
26,001	7.15	128,001	4.83
28,001	7.04	130,001	4.81
30,001	6.94	132,001	4.79
32,001	6.85	134,001	4.76
34,001	6.76	106,001	4.74
36,001	6.67	108,001	4.72
38,001	6.59	136,001	4.70
40,001	6.52	138,001	4.67
42,001	6.45	140,001	4.65
44,001	6.38	142,001	4.63
46,001	6.31	144,001	4.61
48,001	6.25	146,001	4.59
50,001	6.19	148,001	4.57
52,001	6.13	150,001	4.55
54,001	6.07	152,001	4.53
56,001	6.02	154,001	4.51
58,001	5.97	156,001	4.49
60,001	5.92	158,001	4.47
62,001	5.87	160,001	4.45
64,001	5.82	162,001	4.43

**Table 6 (continued): MPG Assumptions (Initial MPG)**

Declared	MPG	Declared (cont.)	MPG (cont.)
66,001	5.78	164,001	4.42
68,001	5.73	166,001	4.40
70,001	5.69	168,001	4.38
72,001	5.65	170,001	4.36
74,001	5.61	172,001	4.34
76,001	5.57	174,001	4.33
78,001	5.53	176,001	4.31
80,001	5.49	178,001	4.29
82,001	5.45	180,001	4.28
84,001	5.42	182,001	4.26
86,001	5.38	184,001	4.24
88,001	5.35	186,001	4.23
90,001	5.31	188,001	4.21
92,001	5.28	190,001	4.19
94,001	5.25	192,001	4.18
96,001	5.22	194,001	4.16
98,001	5.19	196,001	4.15
100,001	5.16	198,001	4.13
102,001	5.13	200,001	4.12

See: *MPG* tab, HCAS Inputs 2015.xlsx

**Table 7. 2015 HCAS Data Files and Sources**

Data	Source	File Name
Bridge Project Information	ODOT	Project Costs - Final Rpt Sep 2014 (b)with br numbers.xlsx, 2015_HCAS_BR_Length.xlsx
DMV Registration Data	ODOT/DMV	2011-2013 VMT by type.xlsx, dmv_plates.xlsx, dropTag.docx, HCAS_DMV_2013_12_all.csv, HCAS_DMV_2013_12.csv
Federal Fleet Report	<a href="http://www.gsa.gov/portal/category/102859">http://www.gsa.gov/portal/category/102859</a>	2013 Federal Fleet Report. US General Services Administration (GSA).
FHWA Highway Statistics-Table MV7		FHWA Highway Statistics-Table MV7 (2012): mv7.xls
FHWA Highway Statistics-Table VM2	Office of Highway Policy Administration, FHWA	FHWA Highway Statistics-Table VM2 (2012): vm2.xls ( <a href="http://www.fhwa.dot.gov/policyinformation/statistics/2012/vm2.cfm">http://www.fhwa.dot.gov/policyinformation/statistics/2012/vm2.cfm</a> )
Flat Fee Collections Reports	ODOT	LOGS_100pc_95pc_90pc_85pc_80pc_2013.xlsx, SAND&GRAVEL_2013.xlsx, FINAL_2013_FLAT_FEE_STUDY.docx
OR HPMS Submittal Data	ODOT	Sample_Details.zip, Submit_2013_41_Metadata.csv, Submit_2013_41_NAAQS_Summaries.csv, Submit_2013_41_Sample_Sections_Details.csv, Submit_2013_41_Sample_Sections.csv, Submit_2013_41_Summaries.csv, Submit_2013_41_Urban_Summary.csv, Submit_2013_41_Vehicle_Summaries.csv
Local Costs: Local Roads and Streets Survey	ODOT	2013 Survey Form Combined City County_summary.xls
Motor Carrier Registrations	ODOT/MCTD	BKPLTS_YR2013.TXT, HUS_2013_WM.csv, Or_plates_2013.csv
Non-Project Costs	ODOT	Costs to Allocate Report_2014_Final.xlsx
Pavement Factors	Roger Mingo, Mingo and Assoc.	Calc Pave Shrs 2014 v3f.xlsm, gwdist.xlsx, relative_shares.xlsx
Project Costs	ODOT	Project Costs - Final Rpt Sep 2014 (b).xlsx, Project Costs - Final Rpt Sep 2014 (c).xlsx, Project worktypes.xlsx
Studded Tire Expenditures	ODOT	Figure 5.5, Review of Studded Tires in Oregon, Final Report, SPR 304-671, December 20, 2014, ODOT Research Section
VMT Forecast	ODOT	VMT Forecast for HCAS_2015.xls
Revenue Forecast	ODOT	Transactions & Revenues 2013-15.xls, Transactions & Revenues 2015-17 v2.xlsx
RUAF Collection reports	ODOT/MCTD	RUAFRPT.TXT
Transit VMT: Salem-Keizer Transit	Gregg Thompson, Salem-Keizer Transit	
Transit VMT: TriMet	Steve Callas, TriMet	
Weigh-In-Motion Data	Portland State University/ODOT	wimdata_2013.csv, wim_tags.csv, transponders.csv
WMT Collection Reports	ODOT/MCTD	WM_HUS_2013.csv, wmt.csv