APPENDICES

TO THE

HIGHWAY COST ALLOCATION STUDY 2011-2013 BIENNIUM

Prepared for
Oregon Department of
Administrative Services,
Office of Economic Analysis

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Oregon Highway Cost Allocation Study

2011-2013 Biennium

Appendix A

Glossary of Highway Cost Allocation Terms

List of Acronyms

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

Appendix B

Oregon Highway Cost Allocation Study

2011-2013 Biennium

Issue Papers

Issue Paper 0:

Traditional and Efficient Fee Approaches to Highway Cost Allocation

1.0 Introduction

The purpose of highway cost allocation studies is to determine whether each class (however defined) of highway users is paying their fair share. Paying one's fair share is defined as contributing the same share of total revenues that one imposes of total costs.

Each user class's share of revenues is the revenues generated by that class divided by the sum of revenues generated by all classes.

$$share\ of\ revenues = \frac{revenues_i}{\sum_{i=1}^{n} revenues_i}$$

Each user class's share of costs is the costs imposed by that class divided by the sum of costs imposed by all classes.

$$share\ of\ costs = \frac{costs_i}{\sum_{i=1}^{n} costs_i}$$

The ratio of these two ratios, called the equity ratio, measures the extent to which a user class pays its fair share.

$$equity\ ratio_i = \frac{share\ of\ revenues_i}{share\ of\ costs_i}$$

If the equity ratio for a particular class is 1.0, that user class is paying exactly its fair share. If the equity ratio is more than 1.0, the class is paying more than its fair share. If the equity ratio is less than 1.0, the class is paying less than its fair share.

A user class could be any subset of users. The definition of user classes determines, in part, the outcome of the study, so it is important that user classes are defined in a way that is useful to answering the questions posed for the study. For the Oregon Highway Cost Allocation Study (HCAS), user classes are defined in terms of vehicle weight to support the constitutional mandate for monitoring equity between light and heavy vehicles. *Light vehicles* are defined as all motor vehicles weighing 10,000 pounds or less, from motorcycles to Hummers. Vehicles weighing more than 10,000 pounds are assigned to classes in 2,000-pound increments. Classes for vehicles weighing more than 80,000 pounds are defined by weight increment and number of axles (5, 6, 7, 8, or 9+). User class definitions for non-light vehicles in Oregon consists of 2,000-pound increments because the rate schedule for the weight mile tax (WMT), paid by commercial vehicles weighing between 26,001 and 105,500 pounds, is in 2,000-pound increments rather than the 5,000-pound increments used in the federal HCAS. Vehicles weighing between 80,000 and 105,500 pounds pay weight-mile tax rates from "Schedule B", which vary by both weight and number of axles. All vehicles weighing over 200,000 pounds are contained in a single "over 200,000" weight class.

Traditionally, highway cost allocation studies have redefined *costs imposed* to mean "budgeted future expenditures by highway agencies" and then allocated those expected expenditures out to vehicle classes without regard to the adequacy or efficiency of those expenditures. The efficient fee approach attempts to more accurately estimate the costs that actually are imposed by each class by imagining a system of fees that recover the actual costs imposed and then determining how much each class would pay under that imaginary, efficient fee system.

The concept of fairness is the same in the two approaches, but fairness, as expressed in the equity ratio, is measured differently.

2.0 Differences Between Traditional and Efficient Fee Approaches

2.1 Revenue Attribution is the Same in the Two Approaches

Highway revenues come from a variety of taxes and fees defined in current law. In Oregon, these include motor fuel taxes, vehicle registration fees, weight-mile taxes, road use assessment fees, and flat fees. Revenue attribution estimates the amount of each fee vehicles in each class will pay under current-law fees and then add them up for each class across the various fees they pay.

2.2 Cost Allocation is Different Between the Two Approaches

The concept of fairness is the same in the two approaches, but the share of cost, as expressed in the denominator of the equity ratio, is measured differently.

2.2.1 The traditional approach

The traditional approach does not attempt to directly measure the costs imposed on the system by different classes of vehicles. Instead, it starts with the assumption that the amount of planned expenditure is exactly equal to the costs imposed by vehicles. It maintains this assumption no matter how much evidence exists that parts of the system are deteriorating or excessively congested (indicating that expenditures have been too low) or that parts of the system are overbuilt or underutilized (indicating that expenditures have been too high).

In Oregon, the expenditures traditionally included in an HCAS are the expected expenditures of state highway user fees, a portion of the expenditure of state bond revenues, federal highway funds, and certain local government revenues within a fiscal biennium. Oregon also treats as a "cost" the difference between what alternative-fee-paying vehicles would pay if they paid "regular" fees and what they actually pay. In Oregon, expenditures of bond revenues are scaled so that only two years' worth of debt repayment are allocated; the remainder of the allocated cost of repayment is carried forward to future studies (nine future studies in the case of 20-year bonds).

In reality, there always are differences between the amount expended in a biennium and the costs imposed in that biennium. The expected life of a capital project will likely exceed the study horizon. Deferred maintenance may result in maintenance expenditures that are lower than costs in one study period and higher in another. Users may also impose costs, such as those resulting from pollution and noise, that are not borne by highway agencies and thus are not counted among expenditures in any time period. The traditional Oregon HCAS recognizes that this is the case, but continues to define costs as expenditures because expenditures can be measured more directly (and more accurately) and are closely linked to the definition of revenue.

Once cost categories are defined, expenditures can be estimated from agency budgets and divided into categories reflecting different allocations of costs among user classes. Major categories include:

- Construction costs for new facilities
- Construction costs for preservation projects
- Right-of-way
- Engineering
- Maintenance
- Overhead (expenditures that vary with overall construction activity but are not tied to any particular project)
- Administration (expenditures not closely related to the use of highways)

These major categories are further subdivided to account for differences in how costs for different kinds of facilities are allocated. For example, the same vehicle might impose different wear and tear costs per mile when driving on asphalt pavement than when driving on concrete pavement.

Once costs are categorized, an allocation method for each category needs to be specified and applied. The only requirement is that the final sum of the allocated costs equals the original sum of costs to be allocated. The choice of allocation methods has been covered in other, longer papers. Factors involved in choosing an allocation method include: whether the expenditure creates new highway capacity, what kinds of vehicles use the facility or service, and whether the facility could have been built more cheaply if heavier vehicles were to be excluded from using it.

2.2.2 The efficient fee approach

The efficient fee approach attempts to more accurately estimate the costs that are actually imposed by each class by imagining a system of fees that recover the actual costs imposed and then determining how much each class would pay under that imaginary, efficient fee system.

The efficient fee approach starts with the presumption that every vehicle could be charged a fee for each mile it travels that is equal to the costs it imposes in that mile. The charge will vary with the time and place the vehicle operates as well as the attributes of the vehicle, such as length, weight, and number of axles. It consists of several components:

- A congestion fee component 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 amount by which that vehicle slows traffic and the value of other travelers' time. Because the congestion fee is not actually in effect, road users are not currently responding to it; the estimated collections from an imaginary congestion fee based on current congestion levels are much higher than collections under an actual congestion fee would be. For this reason, the present study uses the congestion fee each user class would pay under current congestion levels to determine that class's cost-responsible share of congestion costs, but scales the estimated collections down so they sum to the amount that would be collected if the fees were actually in place.
- Wear-and-tear fee components 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 and preservation and does not depend on actual expenditures in any particular biennium or the cost-effectiveness of actual maintenance and preservation programs.
- An administrative fee component recovers the cost of highway agency activities not directly covered by the congestion or wear-and-tear fees, such as planning, administration, human resources, and information services. As in the traditional approach, there is no right way to allocate these costs to individual vehicles, so a "least wrong" allocation method must be chosen and applied.
- An emissions fee component recovers 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.
- Components representing fees for other externalities imposed by vehicles could be included as well. This study does not include fees for other externalities. 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 produced of the externality, and there must be a defined cost (which may be negative in the case of an external benefit) per unit of externality. Potential other externalities include the following:

- Noise
- Water pollution
- Safety

Once the appropriate levels for the efficient fees have been determined, the amount of fees that would be paid by each user class is calculated. Because the fees are set to reflect costs imposed, the estimated amount of fees each class would pay is an estimate of the costs that class would impose.

Note that the amount of fees that each class would pay is calculated assuming no change in behavior from the case where current-law fees are charged. To evaluate the extent to which current-law fees equitably charge vehicle classes for their use of the highway system, it is necessary to model the behavior under current-law fees. The results of this analysis, therefore, do not reflect what would happen if efficient fees actually were charged and travelers changed their behavior in response.

2.2.3 Data requirements for the efficient fee approach

Since revenue attribution is the same under the two approaches, all of the data collected for revenue attribution under the traditional approach are both necessary and sufficient for the efficient fee approach.

The data about expenditures that are collected for the traditional approach are not directly relevant to the efficient fee approach except for determining the amount to be recovered by the overhead charge, but likely will be useful for estimating unit costs of different activities. Some of the rest of the data used to allocate costs under the traditional approach are relevant and useful for the efficient fee approach, especially all of the data about vehicle miles traveled.

Some additional data that are not used in the traditional approach are necessary for the efficient fee approach. These include data used to estimate wear-and-tear costs per mile traveled for different vehicle classes and data used to estimate congestion costs imposed per mile traveled for different vehicle classes on different roads at different times.

Data for the calculation of the wear and tear charge components will include engineering data relating use by vehicles of different classes to consumption of useful life and per-unit cost data to value what is being consumed. We expect that the expenditure data obtained for the traditional approach will provide a basis for much of the per-unit cost data and has the advantage of being current and Oregon-specific. Where necessary, we will rely on construction cost manuals used by estimators to fill in gaps. The engineers on the team will be responsible for obtaining relevant engineering data.

Data for the calculation of the congestion charge will come from traffic counts, especially automatic traffic recorder data, and from roadway characteristics (functional class, number of lanes, etc.) obtained from the Highway Performance Measurement System, ODOT, and local sources. We will use formulas from the AASHTO Highway Capacity Manual and the AASHTO Manual for User Benefit Analysis to calculate the congestion charges from these data.

Data for calculation of the overhead charge will come from the expenditure data collected for the traditional approach.

Data for the optional emissions charge will include data relating travel by vehicles of different classes to the production of various emissions and data on the cost of damage imposed per unit emitted of each pollutant. In the case of fuel-burning vehicles, carbon dioxide emissions are directly related to the amount of fuel burned, so the miles-per-gallon estimation that is already built into the model can be used in the emissions calculations. Emissions charges for plug-in electric vehicles will be based on data about the sources for electricity that is sold in Oregon.

If charges for other externalities are included, the data used to calculate them will be similar to the data for emissions charges, with data relating travel to the production of the other externality and data valuing damage per unit of the externality.

3.0 Differences Between the Efficient Fee Approach to Highway Cost Allocation and Efficient Pricing

The efficient fee approach offers valuable insights into how different vehicles impose costs on the highway system, but, as applied in this study, it does not actually impose efficient fees on individual vehicles. Implementing efficient fees (i.e., an efficient pricing system) would yield several important advantages over the traditional highway user approach, including:

- Each vehicle would pay the costs it imposes, which is always its fair share. This is more fair than requiring only that the unfairness in what individual vehicles pay balance out over all the vehicles in a weight class.
- Each vehicle would pay the costs it imposes, 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 approach, 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 fees collected from efficient congestion fees over time would adequately fund efficient infrastructure enhancements. The inherent lumpiness of construction expenditures could be handled through borrowing against future congestion fee receipts.
- The collections from efficient wear-and-tear fees would adequately fund efficient maintenance and preservation activities over time.
- Efficient emissions fees would lead to socially optimal emissions levels (maximizing the net benefits of travel less the costs of emissions) while providing additional collections that could be used to offset the administrative costs of managing the highway system.
- In the long run, efficient pricing would lead to more efficient land use and transportation infrastructure through voluntary rearrangements that are beneficial to those making the changes.

Issue Paper 1:

An Efficient Congestion Fee

1.0 Introduction

When a road becomes congested, the congestion imposes significant costs on the users of the road. In many cases, the cost of adding capacity to the congested road is less than the cost of congestion borne by the users of the road, so spending highway user fees on adding capacity is warranted and cost beneficial. A large part of the Oregon Department of Transportation's (ODOT's) capital construction budget is spent on adding capacity to facilities that have become congested.

Congestion costs are the incremental costs that users' vehicles impose on other vehicles within the traffic stream in which they operate. An individual user bears his own portion of the total increase in delay by being delayed himself in the traffic stream. But his presence in the stream imposes costs in the form of additional delay on all of the other users in the stream as well. This cost arises as a consequence of the inherently congestible nature of roads, but will only be significant when traffic volumes approach the capacity of the roadway.

Under the efficient fee approach to highway cost allocation, cost responsibility is allocated as it would be if efficient prices were levied for highway use. Efficient pricing would levy charges differentially depending upon the vehicle's specific burden on capacity and maintenance. A key aspect of the efficient fee approach is that a vehicle is charged for its contribution to a roadway's congestion. Because that contribution to current congestion is what drives the need for new capacity, this congestion charge can be thought of as a capacity charge. The efficient fee approach to capacity charges (called congestion pricing) will result in charges that are greater on congested road segments. Charges will also be greater if the vehicle is slow, large, or otherwise uses up more scarce capacity. In contrast, no vehicle would pay a capacity charge if traffic is sparse enough that it doesn't interfere with the progress of other vehicles.

The purpose of this paper is to describe a method and data sources that may be used to estimate the efficient fees for congestion that would prevail given current capacity, expected traffic volumes, and no change in behavior. Because efficient fees will not be charged during the study period, behavior will not change, so the efficient congestion fee approach estimates responsibility for capacity costs under current-law revenue instruments, which is the goal of a highway cost allocation study.

When projects that add capacity are paid for through traditional revenue instruments (e.g., fuel taxes and registration fees), users of every road in the state contribute to the funding of congestion relief, even if they never themselves contribute to congestion by traveling on congested roads at congested times.

Using the efficient fee method does not solve the problem of charging individual users for capacity costs they do not impose, but it does allow for more accurate estimation of the cost responsibilities attributable to vehicle classes. This is because instead of taking planned expenditures on capacity, which will vary from year to year and may not represent optimal investment levels in any year, and spreading them over vehicle classes, the efficient fee method estimates the cost responsibility for individual vehicles on individual road segments and aggregates them up to vehicle classes.

If congestion fees are properly set and investments are managed efficiently, congestion fees will generate just enough revenue to finance capacity throughout time. The logic of this conclusion is subtle, but important. The key point is that pricing and investment are both focused on balancing user costs and benefits.

Congestion fees indicate the value of new capacity. If congestion fees are high, it is because traffic delays are great. Hence, if these costs could be relieved through investment, the saving of these costs would be a benefit of the investment.

Optimal investment policy balances these benefits against the investment cost of providing additional capacity (or relieving congestion in other ways). The investment rule says simply that road improvements should be undertaken if their benefits exceed their cost. Capacity improvements tend not to be built, therefore, unless the costs imposed by the insufficiency of existing capacity exceed the cost of building additional capacity.

In this sense, efficient fee pricing tends to generate sufficient revenue to finance highway improvements if investment follows the investment rule. The technical conditions under which this occurs have been studied in the literature by a number of authors, and they are easily met. The lumpiness of capacity investments (it makes no sense to add one tenth of a lane each year for ten years) often requires that financing methods be employed to make large investments in single years that are funded by efficient fees collected over many years.

The relevance of all of this to highway cost allocation is that the relative importance of capacity costs and preservation and maintenance costs is determined automatically under the efficient fee method and does not vary with random changes in construction budgets. Capital construction projects tend to be expensive and durable. In years when large capital projects are built, there is less money available to spend on preservation, but that is made up for in other years when fewer capital projects are built. These swings in project-type emphasis change the cost allocation under the traditional approach, but do not affect the results of the efficient fee approach except by lowering future congestion fees after capacity increases.

2.0 Implementing the Efficient-Pricing Approach

To precisely implement the efficient pricing approach, it is necessary to do the following:

- Determine the level of congestion, for each road segment for each moment of the day for each day of the study period. The level of congestion is measured as the ratio of volume to capacity and thus depends on both traffic levels (measured in passenger-car equivalents [PCEs]) and the capacity of each segment (measured in PCEs).
- Determine the delay imposed on other vehicles by the addition of one vehicle to the traffic stream for each road segment at each moment of each day for each day of the study period. This is the marginal total delay minus the delay experienced by the marginal vehicle and is a function of both the volume of traffic and the ratio of volume to capacity as well as the length of the segment and the speed at which traffic flows on that segment when there is no congestion.
- Determine the value of the delay imposed on other vehicles by the addition of one vehicle to the traffic stream for each road segment at each moment of each day for each day of the study period. This is the number of minutes each of the other vehicles are delayed times the value of time per minute for each of the other vehicles. The result is the efficient congestion fee for using that road segment at that time.

- Determine the total amount of congestion fees that would be collected from each vehicle class if the efficient fee were imposed on each vehicle on each road segment at each moment of each day. The collections amount must be determined in two ways: as if vehicles did and didn't change their behavior as a result of the fee. The total amount of fees that would be collected if vehicles did change their behavior is the amount that should be collected in total, and the amount that would be collected from each class if they didn't change their behavior determines the proportion of the total that each class should be allocated for the purpose of determining cost responsibility under current law rates.

Although the precise implementation of the efficient fee approach is easy to describe, it is impossible to accomplish with available data. To develop a feasible implementation using available data, we must add some complication and make some assumptions.

2.1 Determining the Level of Congestion

We must get from available traffic count and road-capacity data to a characterization of congestion on different roads at different times. We don't have data about every segment, but each road segment is assigned to one of 12 functional classes based on whether it is rural or urban and whether it is a freeway, arterial, collector, or local street. The likelihood that a road segment will experience congestion is highly correlated with its functional classification. For example, segments on urban freeways and arterials are much more likely to experience congestion than are segments on rural collectors and local roads. Functional classification is included in all of the relevant data and the traditional approach estimates study-period vehicle miles of travel (VMT) for each combination of weight class and functional class. We will measure levels of traffic volume and congestion by time period for the segments for which we have data and then assume that other segments of the same functional classification experience similar congestion levels and patterns. Fortunately, the functional classifications for which data are least available are those that are least likely to experience congestion.

The Highway Performance Monitoring System (HPMS) database contains information about 34,855 road segments in Oregon, including functional classification and capacity. 24-hour automated traffic recorders (ATRs) are permanently installed at fewer than 150 locations in Oregon, all of which are on HPMS segments, and have been temporarily installed at a variety of other locations. Each location is associated with a functional class. From the ATR data, we can develop profiles of traffic volumes and volume-capacity ratios over hours of the day and days of the week for HPMS segments. We can then aggregate them over functional classes to produce functional-class-specific profiles that may be used to characterize road segments that are not in the HPMS database.

2.2 Determining the Delay Imposed on Other Vehicles

The time an individual vehicle will require to traverse a road segment may be estimated from the length of the segment, its free-flow speed (the speed at which vehicles travel when there is no congestion), and the ratio of volume to capacity (a measure of congestion). This relationship is called the volume-delay function or VDF.

Without congestion, the time it takes (in hours) to traverse a segment is the length of the segment (in miles) divided by its free-flow speed (in miles per hour). As congestion increases, the time it takes increases. A common and useful volume-delay function, called the BPR function, is:

$$delay = \frac{L}{FF}\left(1 + \alpha\left(\frac{V}{C}\right)^{\beta}\right)$$

where:

delay is the time in hours it takes to traverse the segment

L is the length of the segment in miles

FF is the free-flow speed in miles per hour

V is the volume of traffic in PCEs

C is the capacity of the segment in PCEs

α and β are parameters appropriate to the segment

Standard values of alpha and beta have been estimated for different functional classes to allow the use of the volume-delay function on segments for which sufficient data do not exist to estimate segment-specific parameters. For example, using an alpha value of 0.1 and a beta value of 10.0 works well for freeways. With those parameters, a length of 1 mile and a free-flow speed of 65 mph, a freeway segment would take 55 seconds to traverse when uncongested (65 mph), 61 seconds when volume is at capacity (59 mph), 107 seconds when volume is at 125 percent of capacity (34 mph), and 375 seconds when volume is at 150 percent of capacity (10 mph). Adding an additional vehicle has little effect when the volume is under the road's capacity, but a large effect when the volume is over capacity. Each additional vehicle has a larger effect than the one before it.

Traffic engineers define the capacity of a road as the volume at which throughput (vehicles passing a point in an hour) is highest. It is not the highest number of vehicles that can fit onto the road. It is therefore possible to have traffic volumes in excess of capacity. Capacity is measured in PCEs. Automobiles are always one PCE each and most heavy trucks are in the range of 2.5 to 4.0 PCEs each.

The delay experienced by all vehicles using a road segment during a time period (the total delay function) may be obtained by multiplying the volume-delay function by the volume (delay per vehicle times number of vehicles equals total delay). The change in total delay associated with the marginal vehicle is then the first derivative of the total delay function with respect to volume, evaluated at the observed volume. The delay imposed on other vehicles by the marginal vehicle is the increase in total delay associated with the marginal vehicle minus the delay experienced by that marginal vehicle itself (obtained from the original volume-delay function). Using the volume-delay function described above, this reduces to:

$$delay\ on\ others = \frac{\alpha\beta L}{FF}\left(\frac{V}{C}\right)^{\beta}$$

The table below shows the estimation of the delay imposed on others by the marginal vehicle on a freeway segment that is 1 mile long and has a free-flow speed of 65 mph at various levels of congestion:

Table 1: Delay Imposed on Other Vehicles

Volume-Capacity Ratio	Delay per Vehicle (seconds)	Speed (mph)	Marginal Total Delay (seconds)	Marginal Delay Imposed on Others (seconds)
0.50	55	65	55	0
0.75	56	65	59	3
1.00	61	59	116	55
1.25	107	34	623	516
1.50	375	10	3,569	3,194

2.3 Determining the Value of Delay Imposed on Other Vehicles

The value of the delay imposed on other vehicles is the delay imposed on other vehicles (in hours) times the average value of time (in dollars per hour) for the other vehicles. Individual vehicles' values of time depend on the number of occupants in the vehicle and on the individual occupants' values of time. Information about an individual's overall value of time is revealed by their wage rate (the value at which they sell their time in the labor market), but may vary depending on the trip purpose, whether they are already late, and the penalty they might face for being late as well as the relative pleasantness of the time spent traveling. Because many people want to get to work on time and find driving in heavy traffic to be less pleasant, observed values of time are higher during peak commuting periods than at other times.

We will make use of information from other settings where travelers' values of time are revealed (where, for example, they have a choice of paying a toll to use a faster lane or staying in a congested lane for free) to develop profiles of values of time for different functional classes at different times of day and then adjust those using the ratio of Oregon wage rates to wage rates in the places where the data were collected.

The value of the delay imposed on other vehicles by the marginal vehicle is the efficient congestion charge for that road segment. From the example above, if the average value of time for other vehicles (taking into account occupancy, functional class, and time of day) were $20.00 per hour, the efficient congestion charge would be 1.7 cents per mile at 75 percent of capacity, 31 cents per mile at 100 percent of capacity, and $2.86 per mile at 125 percent of capacity. The charge is essentially zero when the segment is at 50 percent of capacity or less.

2.4 Determining the Amount of Revenue That Would be Collected From Each Vehicle Class

To estimate the revenue that would be collected from each vehicle class under an efficient congestion charge, one would multiply the per mile charge for each vehicle class (which takes into account PCE per vehicle for that class) for each functional class at each time of day by the volume (in VMT) of vehicles in that class on that functional class at that time of day and sum them over all functional classes and times of day.

The revenue that would be collected from all vehicle classes under an efficient congestion charge that was actually imposed and that vehicle operators responded to is the amount of congestion cost that should be allocated to vehicles because it represents the amount necessary to fund efficient investments in capacity in the long run.

The revenue that would be collected from each vehicle class under the same set of efficient congestion charges, but without actually imposing them and without a change in vehicle behavior, determines the proportion of congestion cost that should be allocated to that vehicle class under the efficient fee method of highway cost allocation.

2.5 Data Limitations

The main challenge in implementing the efficient congestion fee in highway cost allocation is that the necessary data are not available for every road segment. There are numerous limitations to the available data in the context of an efficient pricing approach:

- Hourly vehicle counts, by vehicle type, are available for fewer than 150 road segments out of the 34,855 segments in the HPMS database. Therefore, it is necessary to apply the vehicle activity distributions from a limited number of segments to all of the segments in the Oregon system.
- Vehicle count information is available for 14 vehicle types (13 federal configurations plus triples), but not by weight class. Consequently, it is necessary to link vehicle types to vehicle weight classes.
- There are no officially adopted volume-delay relationships for each road segment. It is necessary to attribute such relationships using functional-class information from the HPMS. For the efficient fee method, standard BPR volume-delay relationships will be applied to each segment with standard parameters appropriate to the segment's functional classification; these do not account for facility grade or other unique features.

Issue Paper 2:

An Efficient Wear-and-Tear Fee for Pavement

1.0 Introduction

This paper describes the background and derivation of a method for determining an efficient wear-and-tear fee for pavement. Because this method derives the marginal cost impose'd by a vehicle of a given weight and axle configuration on a given road as a linear function of the average cost, it could be used to scale the cost allocation factors, by functional class, from the traditional method for use in the efficient-fee method.

2.0 Optimal Investment

Transportation infrastructure may be build using a variety of designs, materials, construction techniques, and specifications. The resulting products serve the same purpose (carrying vehicles) but differ in capacity, strength, durability, resistance to environmental damage, construction cost, maintenance cost, and useful life.

The wear and tear imposed on a road by traffic in a year depends on the number of vehicles, the weight of axle loads from each vehicle, the speed of the vehicles, and the weather. Heavier axle loads damage pavements much more than lighter loads (the damage increases in proportion to the cube of weight), but the amount of damage depends on the characteristics of the pavement (how thick it is and what it's made of), the strength and stability of the base under the pavement, and the condition of the pavement (once pavement starts to break apart, it deteriorates rapidly). If pavement could be perfectly smooth, vehicle speed would not matter, but it can't and the force with a tire strikes an irregularity on the surface is proportional to the square of speed. Studded tires tear up the surface of pavements when there is not a layer of snow or ice between the studs and the pavement. The damage imposed by studded tires increases with the square of speed, all else equal.

Given expected levels and compositions of traffic over time, an expected set of environmental conditions, and a set of expected prices for materials, labor, etc., there exists an optimal investment strategy for a road segment: the one where the present value of costs over time is lower than any other. From an agency perspective, this would include design, right-of-way, access, construction, maintenance, preservation, and reconstruction costs. From a user's perspective, it would include all of those (to the extent they are included in user fees) as well as user-borne costs such as delay and vehicle operating and maintenance costs. From society's perspective, it would include all of the above plus external costs borne by nonusers. The efficient-fee approach prices the user delay and external costs separately, so for determining the wear-and-tear component of the efficient fee, we will focus on the agency-borne costs.

The optimal investment strategy depends greatly on the volume and composition of traffic. For a road that is expected to carry high volumes of heavy axle loads, it makes the most sense to build a solid, well-drained base with thick, rigid pavement. High initial construction costs are more than made up for by reduced maintenance and preservation costs over time. Heavy vehicles could be charged the full (amortized) extra construction cost plus the (low) maintenance and preservation costs they impose on the durable pavement and still pay much less that if they were charged the (high) maintenance and preservation costs they would impose on thin, flexible pavement. On the other hand, if a road is not expected to carry many vehicles, the savings in maintenance and preservation costs would never make up for the extra construction cost of building a durable road.

2.1 Units of Use

Because the amount of wear and tear imposed by vehicle depends greatly on the weight on the vehicle's axles as it passes over the road, measures of the number of vehicles, such as average daily traffic (ADT) and vehicle miles of travel (VMT), do not provide good indicators of the wear and tear a particular traffic stream will impose. For this reason, engineers have developed alternative measures of traffic load, such as equivalent single-axle loads (ESALs) and load equivalence factors (LEFs).

2.2 Average Cost

Given some chosen investment strategy, the average cost per unit of use will be high at low-use levels, fall as fixed construction costs are spread over more units of use until usage matches the level for which the investment strategy was optimized, and then rise again as maintenance and preservation costs per unit of use rise (because the facility was under-built for the usage it experienced). This is another way of looking at the investment-optimization process. The usage level for which an investment strategy is optimized determines the minimum-cost usage-level under that investment strategy.

2.3 Marginal Cost

The marginal wear-and-tear cost is the additional cost imposed by an additional unit of use. Like the average cost, it depends on the level of use, but unlike the average cost, it generally increases over the relevant range of use levels. This is mostly a result of shifting future maintenance and preservation activities closer to the present, increasing the present value of their cost.

Given some chosen investment strategy, the marginal cost will equal the average cost at the usage level where the average cost is minimized. As a result, average cost pricing and marginal cost pricing result in the same prices when engineers with perfect foresight are able to perfectly optimize the investment strategy. When usage exceeds the optimal usage level for a facility, marginal costs will exceed average costs and marginal cost pricing will produce more revenue than will average-cost pricing. When usage falls short of the optimal level, marginal costs will be lower than average costs.

Marginal cost pricing produces the amount of revenue necessary to optimize the system over time without requiring perfect foresight. Average-cost pricing "locks in" non-optimal investment levels that inevitably result from imperfect foresight. By incorporating a wear-and-tear fee based on marginal costs imposed, and recalculating that fee periodically as the system and usage levels change, efficient-fee pricing combined with a policy of spending the revenue on the facilities from which it was collected, pushes the system toward optimality over time.

The advantages of marginal cost pricing derive from the effect they have on behavior. They guide users to make optimal use of different facilities and guide agencies to make optimal investments in facilities. Highway cost allocation doesn't change behavior, so the advantages of marginal cost pricing do not accrue form using marginal costs within highway cost allocation. The advantage to highway cost allocation is that the right level of costs are allocated and are properly allocated among vehicle classes. Getting the levels right is important because different categories of costs are allocated differently and the dollar amount allocated in each category affects the overall results.

3.0 Estimating Pavement Wear-and-Tear Charges for Efficient-Fee Highway Cost Allocation

The traditional approach produces relative cost factors that may be scaled so that one unit of use has a cost factor of 1.0. These represent proportional average costs imposed by vehicles of different weights and configurations on roads by functional class as they exist in Oregon.

Small, Winston, and Evans present a set of equations that derive the marginal cost of pavement wear and tear from the average cost. The additional pieces of information needed are:

- The overlay interval in years
- The discount rate
- The traffic growth rate
- The environmental deterioration rate (determined by weather conditions)
- The structural number (a measure of thickness) of the pavement
- The proportion of overlay cost that is pavement (and not labor or equipment)
- Whether the pavement is rigid or flexible

The additional information is used to calculate three factors and the average cost is multiplied by the product of the three factors to obtain the marginal cost. The product of the three factors is one when the traffic growth rate is zero and the original design was optimized for the current level of traffic. Because the marginal cost is a linear function of average cost, the proportional cost factors for different weight classes will not change unless and until the investment strategy changes the characteristics of the pavement.

To set the actual level of the wear-and-tear charge, we will multiply the appropriate relative cost factor by the VMT for each combination of weight class, axle count, functional class, and pavement type and then divide the sum of those into an estimate of the total cost of properly maintaining and preserving the current system. The resulting factor may then be multiplied by each relative cost factor to obtain average-cost prices per VMT. Those may then be scaled by the product of the factors from the Small, Winston, and Evans equations to obtain marginal cost prices.

$$\frac{MC}{AC} = \left[(rT)^2 e^{rT} \big/ \left(e^{rT} - 1\right)^2\right]\left[\left(\left(1 - e^{-fT}\right)/fT\right)e^{mT} \big/ \left(1 + mT\left(1 - e^{-fT}\right)/fT\right)\right]\left[1 + \frac{k_2}{k_m}(D+1)\left(e^{fT/A_1} - 1\right)\right]$$

where:

MC = marginal cost

AC = average cost

T = overlay interval in years

r = discount rate

f = traffic growth rate

m = environmental deterioration rate (ranges from 0.01 for dry, warm to 0.07 for wet, freezing; 0.04 is typical)

$\frac{k_2}{k_m}$ = proportion of overlay cost that is pavement (0.07 default)

D = structural number (measures thickness; 0.44*pavement+0.14*base+0.11*sub-base)

A_1 = coefficient on ln(D+1) in pavement life equation

5.04 for rigid or 7.76 for flexible

Issue Paper 3:

An Efficient Wear-and-Tear Fee for Structures

1.0 Introduction

Under efficient pricing, the initial cost of a new structure is paid from capacity charges, and the cost of future structures to replace the new structure when it wears out is paid from a wear-and-tear fee, along with the cost of routine maintenance.

As with pavements, the correct wear-and-tear fee is the marginal cost, or the change in total cost imposed by the marginal user. Marginal cost per unit of use may be determined by taking the first derivative of the total cost function with respect to use. The total cost function measures the present value of future expenditures taking into account the effects of aging, the current amount of use, future growth in use, and the discount rate.

The efficient fee approach seeks to determine the effects of use by vehicles of different weights on the full lifecycle costs of a structure. Even if it is never used, a structure will eventually deteriorate to the point where it could not safely be used and must be replaced. If a structure is used, it will wear out faster, and the more it is used, the faster it should wear out. Use by a heavy vehicle is likely to impose more stress and wear on a structure than use by a light vehicle. With appropriate engineering data, one could estimate the marginal cost imposed by a vehicle of a given weight. The study team sought such engineering data, but the necessary engineering studies have not yet been conducted. This issue paper describes how one could develop a wear-and-tear fee for structures if the necessary engineering data existed.

The data needed for developing a wear-and-tear fee would not be used in the actual practice of bridge engineering or management. Safe operation requires periodic inspection and rating of every bridge, and maintenance and replacement activities are driven by the results of those inspections. The ability to predict when a bridge will wear out under varying levels of use is not useful to the agencies responsible for operating bridges because they care only about the actual condition of the bridge today and not about what condition it would be in had past usage had been different than it was.

2.0 The Effect of Aging on Consumption of Useful Life

Aging degrades the structure at some rate over time. We can reasonably model the effects of environmental degradation as exponential decay in the remaining life of the structure. That means that if engineers can estimate the half-life, or the number of years it would take for environmental degradation to consume half the useful life of the structure assuming no use, we can calculate the rate of decay.

Without use, the fraction of total life that remains may be calculated as

$$\textit{remaining life} = e^{-mt}$$

where m is the rate of decay and t is the number of years that have passed.

If h is the estimated half-life, the corresponding value of m may be calculated as:

$$m = \frac{-\ln(0.5)}{h}$$

For example, if a structure has a half-life of 100 years, the value of m is 0.0069315.

3.0 The Effect of Use on Consumption of Useful Life

Given its durability, and ignoring the effects of aging for a moment, a structure will need to be replaced after some amount of use has degraded it to the point where it is no longer considered to be safe.

Use must be measured in units such that each unit of use degrades the structure by the same amount. In the absence of engineering studies to determine the amounts by which vehicles of different weights degrade the structure by passing over it, we make use of information we do have from the engineering studies that form the basis of the incremental approach used in traditional highway cost allocation. Those studies show the costs of building different versions of the same structures with different maximum load ratings. For each of the prototypical structures in those studies, the cost of the structure is linear in the log of maximum weight, with a relatively large intercept term indicating that much of the cost of the structure goes toward holding itself up, and each additional unit of strength adds a lower increment of cost.

In making use of the information we do have, we assume that the relationship between the weight of a vehicle and the costs associated with durability (ability to resist the dynamic effects of loading and unloading over time) corresponds to the relationship between the weight of a vehicle and costs associated with strength (the ability to resist the static effect of a single load at a point in time). We know of no engineering research that proves or disproves the validity of that assumption.

Assuming that a structure is built to support vehicles weighing up to 120,000 pounds (the assumption used in the incremental approach), the ratio of the cost of building a structure to support lighter vehicles to the cost of the full-strength structure may be estimated from:

$$ratio = intercept + coefficient \cdot \ln(vehicle\,weight\,in\,pounds)$$

where the intercept and coefficient are from the table that follows.

If our assumptions about the strength and durability are reasonable, we can use these ratios to define standard units of use. First, we need to define the average weight of a light vehicle: 4,000 pounds seems reasonable. That's more than most cars and less than most SUVs, vans, and pickup trucks. If we find the ratio for a 4,000-pound vehicle from the formula above, we can divide that into the ratio for any other vehicle and have a standardized unit of use. Light vehicles would use one unit for each pass over the structure and heavier vehicles would use more than one unit.

With appropriate units of use and ignoring aging, the useful life of a structure

Structure Type	Intercept	Coefficient	R^2
Single Span < 125’	-0.673336	0.143289	0.9928
Single Span > 125’	-0.627871	0.139271	0.9833
Multi-Span	-1.191209	0.176695	0.8167
Interchange	0.136221	0.072014	0.8932

Ratios	Vehicle Weight				
Structure Type	4,000	25,000	53,000	79,000	105,000
Single Span < 125’	0.5151	0.7777	0.8854	0.9426	0.9833
Single Span > 125’	0.5272	0.7825	0.8871	0.9427	0.9823
Multi-Span	0.2743	0.5981	0.7309	0.8014	0.8517
Interchange	0.7335	0.8655	0.9196	0.9483	0.9688

Units	Vehicle Weight				
Structure Type	4,000	25,000	53,000	79,000	105,000
Single Span < 125’	1.00	1.51	1.72	1.83	1.91
Single Span > 125’	1.00	1.48	1.68	1.79	1.86
Multi-Span	1.00	2.18	2.66	2.92	3.10
Interchange	1.00	1.18	1.25	1.29	1.32

may be defined in terms of some number of units of use.

$$L_0 = \frac{N}{Q}$$

where L_0 is the useful life in years (ignoring aging), N is the number of units of use composing the useful life of the structure, and Q is the number of units consumed each year.

4.0 Estimating Useful Life With Both Aging and Use

With both aging and use, the useful life of a structure is shorter than the calculation above would indicate. The useful life is used up when the portion consumed through use is equal to the portion remaining after aging.

$$L = t \text{ such that } \frac{tQ}{N} = \mathrm{e}^{-mt}$$

L may be approximated by applying one iteration of Newton's method.

$$L = L_0 - \frac{\ln(L_0) + mL_0 + \ln\left(\frac{1}{L_0}\right)}{\frac{1}{L_0 + m}} = L_0 - \left(\ln(L_0) + mL_0 + \ln\left(\frac{1}{L_0}\right)\right)(L_0 + m)$$

For example, if N/Q was 75 years and the half-life was 100 years, implying an m value of 0.0069315, the useful life would be about 50 years.

5.0 Present Value of Costs Given Useful Life

The cost of the replacement structure to be built at the end of the initial structure's useful life, and the structure that will replace that one, and so on, may be discounted to present value and added to the cost of the initial structure to determine the present value of providing a serviceable structure forever. At any discount rate that is more than zero, the present value into perpetuity is finite and calculable. The present value of the cost of all future replacement structures is

$$PV = \frac{C}{(1+r)^L - 1}$$

where C is the cost of the structure, r is the annual discount rate, and L is the useful life.

6.0 Accounting for Growth in Use Over Time

If use grows over time, the interval between replacements will shrink, increasing the present value of total cost, or the cost of replacements will increase because the replacements were built to be more durable, which would also increase the present value of total cost. Some combination of more-durable replacements and shorter replacement intervals will result in the minimum present value of total cost given the rate of increase in use and taking into account the effects of aging, which are diminished by a shorter replacement interval.

We can find the replacement interval without aging from

$$L_0 = \frac{\ln\left(g\frac{N}{Q} + 1\right)}{\ln(1+g)}$$

where L_0 is the useful life in years (ignoring aging), N is the number of units of use composing the useful life of the structure, Q is the number of units consumed in the first year, and g is the annual rate of growth in use.

For example, assume N = 75 million and Q = 1 million. L_0 would be 75 if Q did not grow. But if Q grows at one percent per year, L_0 becomes

$$L_0 = \frac{\ln\left(0.01\frac{75{,}000{,}000}{1{,}000{,}000} + 1\right)}{\ln(1+0.01)} = 56.24 \text{ years}$$

The effect of aging may be incorporated in the same way as without growth in use, though with the shortened life from use, the effect of aging on the resulting useful life is less dramatic.

Again, one iteration of Newton's method yields a close approximation of useful life. Using the L_0 defined immediately above,

$$L = L_0 - \frac{\frac{Q}{Ng}\left(\left(1+g\right)^{L_0} - 1\right) - \mathrm{e}^{-mL_0}}{\frac{Q}{nG}\ln\left(1+g\right) + m\,\mathrm{e}^{-mL_0}}$$

7.0 Present Value with Growth in Use

With even moderate growth in use over the life of a structure (typically 50 to 100 years), the capacity of the structure (mostly determined by the number of lanes) will limit the ability of the structure to carry more traffic. If there is non-trivial growth in use, it is likely that additional capacity will be added at the time the structure is replaced, either by adding a second structure or by adding width to a single replacement structure. We assume that the cost of increased capacity is linear in capacity, that is, that either two two-lane bridges or one four-lane bridge will cost approximately twice as much as one two-lane bridge. In that case of added capacity, the ratio of Q to N on the replacement structure(s) will be reset to approximately what it was on the initial structure and, if growth in use continues at the same rate, L for the replacement structure will be approximately the same as it was for the first structure. Because the additional capacity in the replacement structure(s) would be paid for from the capacity charge, rather than the wear-and-tear charge, C remains the same, and we may continue to use the simple formula for present value, but with a different formula for L.

$$PV = \frac{C}{\left(1+r\right)^{L_0 - \frac{Q}{Ng}\left(\left(1+g\right)^{L_0}-1\right) - \mathrm{e}^{-mL_0} \Big/ \frac{Q}{nG}\ln\left(1+g\right) + m\,\mathrm{e}^{-mL_0}} - 1}$$

$$PV = \frac{C}{\left(1+r\right)^{L} - 1}$$

8.0 Marginal Cost

Marginal cost in the first derivative of total cost. If we take the formula for the present value of total cost above, substitute in the formulas for L and L_0 with aging and growth in use, and then take the first derivative, we have the formula for marginal cost.

$$\gamma = \frac{\ln\left(\frac{gN}{Q} + 1\right)}{\ln\left(1+g\right)}$$

$$\frac{\mathrm{d}\gamma}{\mathrm{d}Q} = \frac{-gN}{\ln\left(1+g\right)Q^2\left(\frac{gN}{Q} + 1\right)}$$

$$\theta = \frac{Q}{gN}\ln\left(1+g\right) + m\,\mathrm{e}^{-m\gamma}$$

$$\frac{\mathrm{d}\theta}{\mathrm{d}Q} = \frac{\ln\left(1+g\right)}{gN} - m^2\,\mathrm{e}^{-m\gamma}\frac{\mathrm{d}\gamma}{\mathrm{d}Q}$$

$$\lambda = \frac{Q}{gN}\left(1+g\right)^{\gamma} - \frac{Q}{gN} - \mathrm{e}^{-m\gamma}$$

$$\frac{\mathrm{d}\lambda}{\mathrm{d}Q} = \frac{Q}{gN}\ln\left(1+g\right)\left(1+g\right)^{\gamma}\frac{\mathrm{d}\gamma}{\mathrm{d}Q} + \frac{1}{gN}\left(1+g\right)^{\gamma} - \frac{1}{gN} + \mathrm{e}^{-m\gamma}\,m\frac{\mathrm{d}\gamma}{\mathrm{d}Q}$$

$$\beta = \gamma - \frac{\lambda}{\theta}$$

$$\frac{\mathrm{d}\beta}{\mathrm{d}Q} = \frac{\mathrm{d}\gamma}{\mathrm{d}Q} - \frac{\theta\frac{\mathrm{d}\lambda}{\mathrm{d}Q} - \lambda\frac{\mathrm{d}\theta}{\mathrm{d}Q}}{\theta^2}$$

$$\frac{\mathrm{d}PV}{\mathrm{d}Q} = -C\frac{\ln\left(1+r\right)\left(1+r\right)^{\beta}}{\left(\left(1+r\right)^{\beta} - 1\right)^2}\frac{\mathrm{d}\beta}{\mathrm{d}Q}$$

The derivative of PV with respect to Q incorporates the effect of the growth-in-traffic assumption, which is relevant, but causes the derivative to overstate the marginal cost imposed by an additional vehicle, because it also includes the marginal cost imposed by additional, fractional vehicles in subsequent years. We can correct for that by scaling by the ratio of the present value of ungrown traffic to the present value of grown traffic over the life of the structure.

$$MC = \frac{\mathrm{d}PV}{\mathrm{d}Q}\left(\frac{i-g}{i}\right)\frac{\left(1+i\right)^n - 1}{\left(1+i\right)^n - \left(1+g\right)^n}$$

Issue Paper 4:

An Efficient Emissions Fee

1.0 Introduction

The operation of motor vehicles produces air emissions from fuel combustion (exhaust emissions) and evaporation, and also from particulates produced by brake and tire wear. Air emissions are themselves air pollutants, or are precursors, reacting with other gases and particles in the air to form secondary air pollutants. Air emissions impose costs because of their adverse effects on human health, agricultural yields, and plants, animals, and property. In addition to emitting air pollutants, motor vehicles are a significant source of greenhouse gas emissions (carbon dioxide being the primary greenhouse gas). Greenhouse gases contribute to global climate change, the costs of which will be borne many decades in the future.

This issue paper addresses the treatment of air emissions for the efficient fee approach for highway cost allocation. In the efficient fee approach to highway cost allocation, prices are charged for highway use based on the actual costs imposed for each vehicle class, as opposed to the highway expenditures associated with the vehicle classes. Efficient pricing includes charging based on a vehicle's contribution toward roadway wear-and-tear and fixed costs, the vehicle's contribution to roadway congestion, and other external costs imposed by vehicle operation. The costs related to air emissions are externalities because road users do not bear these costs in relation to their road use.

A number of factors influence emission rates, ambient air pollution levels, and the incremental cost of an additional unit of air pollutant. Emission rates vary by vehicle class, primarily because of vehicle size and weight, and are also influenced by numerous other vehicle and operational characteristics. These other vehicle and operational characteristics are engine type, fuel type, age, operating speeds, start and stops, and rates of deceleration and acceleration. The incremental, per unit cost of emissions also varies by location because of ambient emission levels (which are influenced by atmospheric conditions, topography, chemical reactions to other pollutants, seasonal variations in ambient conditions, etc.), exposure levels, and the types of local resources exposed.

The most common approach used to estimate the marginal cost of air emissions is a multi-step valuation process. In this approach, damage functions are first used to determine the physical effects associated with exposure to air pollution. The physical effects are then converted to dollar values based on the costs associated with those physical effects. Valuation methods for the cost of air emissions include using market prices for the value of the damage associated with air emissions; the use of hedonic models (revealed preference) for determining the influence of air quality on housing prices; and also stated preference surveys, where people are asked how much they would be willing to pay to improve air quality visibility. There are also, currently, a few markets for emission trading where one might observe the "market price" per emission credit under cap-and-trade systems. Carbon credits are traded on the European Union Emissions Trading Scheme System, and there are several regional markets for other pollutants such as nitrous oxides and sulfur dioxide, in particular. These markets reveal more about the cost of compliance with regulation than about the value of the damage, however.

The purpose of this paper is to describe the method and data sources that will be used to estimate the efficient emissions fees that would prevail given the current vehicle fleet, expected traffic volumes, and no change in behavior in response to the emissions fees.

The proposed approach for calculating the emissions fee is to determine the per mile emission rates by vehicle class and speed, and then apply the cost, per additional unit emitted, for each pollutant to determine the appropriate emissions fee. This method will produce emissions fees that reflect the incremental cost imposed per unit of emission per vehicle mile.

Because efficient emission fees will not be charged during the study period, behavior will not change, so the efficient emissions fee approach estimates the user responsibility for external emissions costs under current-law revenue instruments, which is the goal of the highway cost allocation study. For an implemented effficient emissions fee to have the desired behavioral response, the closer the efficient fee was to the actual context-specific cost of the vehicle's emissions. In practice, it would be difficult to levy a differentiated emissions fee. However, the "flatter" the emissions charge becomes, the weaker its rationale. Indeed, the use of automobiles by residents is so ubiquitous that one could argue that the driving population is close to the same population that bears the health and economic impacts. In this case, the driver is already bearing the average burden of emissions and levying an undifferentiated ("average" marginal cost) emissions fee simply duplicates that burden. This argument is amplified if the size of the fee and the (in)elasticity of VMT to operating costs in general means there will be little or no change in the quantity of VMT or a positive welfare impact.

This paper first provides background on vehicle emissions and then describes the implementation of the emissions fee through the measurement of per mile emission rates by vehicle class and use of existing estimates on the per unit cost of air emissions.

2.0 Vehicle Emissions

The U.S. Environmental Protection Agency (EPA) regulates air pollutants that are harmful to humans and the environment. Six air pollutants are classified as criteria pollutants and are regulated under the Clear Air Act: carbon monoxide (CO), ozone (O3), particulate matter (measured as PM2.5 and PM10), nitrogen oxides (NOx), sulfur dioxide (SO2), and lead (Pb). With the exception of sulfur dioxide and lead, motor vehicles are a significant source of criteria air pollutants.

Carbon monoxide, nitrogen oxides and volatile organic compounds (VOC) are regulated under the Clean Air Act with grams per mile standards for automobiles. Vehicle manufacturers meet these per mile standards through emissions control systems and vehicle fuel economy. Assuming proper maintenance of emissions control systems, tailpipe emissions do not vary much with vehicle fuel economy, but are mostly a function of vehicle miles traveled (VMT) and vehicle age, because emissions control systems deteriorate with vehicle age and use.

Toxic air pollutants are another category of air pollutants regulated by the EPA. Air toxins are pollutants that cause, or may cause, cancer or other serious reproductive and neurological health effects, or have other serious environmental and ecological effects. The EPA is required to regulate 187 air toxins. Benzene, formaldehyde, acetaldehyde 1,3-butadiene and diesel particulate are all air toxins emitted by motor vehicles.

Like criteria air pollutants, the damages imposed by air toxins are local in nature. There is generally less information known about the effects and cost of most toxic air pollutants compared to the research on criteria pollutants. Less is known about the exact dose-response to air toxins because much of the research on the carcinogenic effects of air toxins relies on laboratory experiments. In these experiments animals are given high doses of the toxins, doses that are much higher than the concentrations of air toxins that people are exposed to in typical ambient air conditions. Thus, the effects at lower concentration levels have been harder to quantify and isolate from other factors.

Carbon dioxide (CO2) is the primary greenhouse gas produced by motor vehicles and is now regulated explicitly by the EPA, although NHTSA has also regulated average fuel economy, which affects CO2 emission levels, since the first CAFE Standard legislation passed by Congress in 1975. Unlike criteria pollutants and air toxins whose effects are local, greenhouse gas emissions contribute to global climate change. Thus a ton of CO2 emitted anywhere in the world has the same contribution toward climate change and the same global marginal cost.

2.1 Implementing the Emissions Fee

The proposed approach for calculating the emissions fee is as follows:

- For each pollutant, calculate the grams per mile emissions rate for different vehicle types and speeds.
- Determine the marginal cost per unit emitted for each type of pollutant.
- Multiply the emissions rate and marginal cost for each pollutant to determine the cost per mile.
- Sum the cost per mile for the different emissions to determine the total emissions fee per mile.

In this paper we address the emissions and costs of those emissions related to vehicle operation. A lifecycle analysis of air emissions related to motor vehicles would account for tailpipe emissions, and also the upstream emissions associated with refinement and transportation of fuels as well as the carbon emissions related to vehicle production.

2.2 Determining the Per Mile Emission Rates

Emission rates express the grams per mile of pollutants emitted by motor vehicles. Mobile source emission models developed by the EPA, U.S. Department of Energy, and U.S. Department of Transportation use vehicle emission rates for determining the total amount of mobile source emissions for use in state implementation plans and air quality conformity modeling required under the Clean Air Act. These mobile source emissions models are based on emission rates that are sensitive to the fleet composition and utilization, operational characteristics, and regional atmospheric conditions (temperatures and relative humidity).

MOVES2010 is the new mobile source emissions model developed by the EPA for state implementation plans (SIP) and transportation conformity analysis. MOVES2010 is capable of calculating emissions rates for 13 vehicle classes and for 16 average speeds. While emission rates can vary across average speed groups, vehicle weight is not an explicit parameter in MOVES2010.

In MOVES2010, emission inventories and emissions rates are based on a “bottom-up” method, where individual vehicle measurements are collected and then analyzed to determine emissions rates, which are applied to fleet characteristics and utilization to determine the total emissions inventories. In a “top-down” approach, total ambient air concentrations are measured and then allocated to different emission sources (mobile source and others) to determine crude emissions rates.

MOVES2010 was developed based on the EPA’s prior mobile source emission model, MOBILE, with enhancements and updates based on millions of additional vehicle emissions measurements from vehicle inspection and maintenance (I/M) programs, remote sensing device (RSD) testing, certification testing, and portable emission measurement systems. The MOVES2010 model also includes updated models of dispersion, as well as state-of-the-practice understanding of the relationship between atmospheric chemistry related to exposure and formation of secondary pollutants.

Because emission rates are sensitive to fleet characteristics, especially fleet composition and vehicle age, mobile source emissions models typically contain some type of simplified fleet model. Fleet models contain information on the fleet composition (vehicle and fuel types), initial age distributions and future model year vehicle sales forecasts, vehicle survival rates, utilization by vehicle age, and speed distributions. For example, in the MOVES2010 information from the fleet model is used to adjust emission rates to reflect the effect of the deterioration of emissions control systems as a function of vehicle age and accumulated mileage. Default national fleet distribution and vehicle activity data are used with county-specific meteorological data (average temperatures and humidity) for calculating emission rates when local fleet information is not available.

For this issue paper, the MOVES2010 model was used to produce sample emission rates for select vehicle classes. Figure 1 displays the grams per mile CO emissions for Multnomah County in 2009 for several model years of passenger automobiles. National default data are used for the fleet and vehicle activity and vehicle vintage distributions.

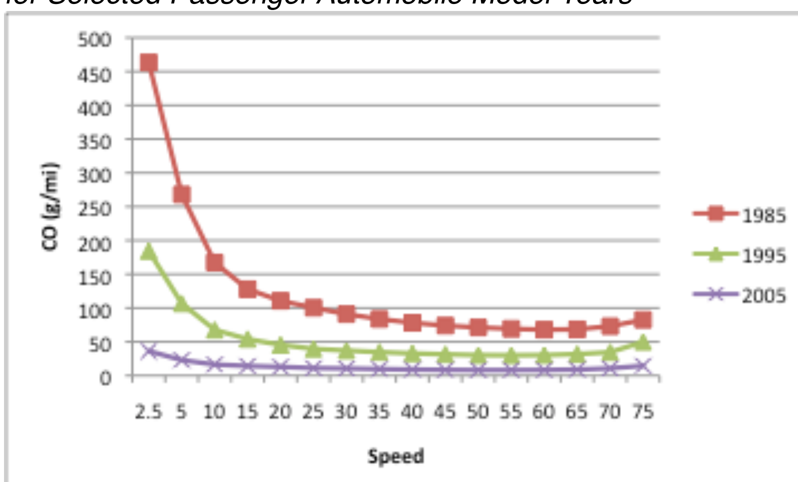
Carbon dioxide emissions are directly related to fuel consumption. The Intergovernmental Panel on Climate Change has issued guidance on the calculation of CO2 emissions based on the average fleet fuel economy and the carbon content of fuels—a very straightforward calculation if average fleet fuel economy is known.

2.3 Determining the Cost Per Additional Unit Emitted

An efficient emissions fee would be assessed on a per mile basis, determined by the per mile emissions rate and the per unit (e.g., per ton) cost associated with the emission of an additional unit of a pollutant. With the per mile emission rates tabulated for each vehicle class and functional class based on output from mobile source emissions models, the remaining parameter needed for the calculation is the per unit cost of an additional unit of pollutant.

Estimates of the per unit cost of air pollution are traditionally calculated using a multi-step, damage-function approach. The first step, in this method, is to determine the change in the ambient air concentration of pollutants from vehicle emissions. Next, the physical effects (damages) associated with exposure to pollutants are determined based on the published epidemiological and scientific literature. Last, the dollar estimate of the cost of an additional unit of pollutant is determined through the monetization of the

Figure 1: Carbon Monoxide Emission Rates (grams per mile) for Selected Passenger Automobile Model Years



physical effects associated with exposure to air pollutants.[1]

The first five damage (cost) categories described below apply to criteria and toxic air pollutants. Global climate change, the last category of damages from air emissions, is caused by greenhouse gases.

The major cost categories associated with air emissions from motor vehicles are:

- *Human-Health Effects*: Human-health effects is the largest category of damages associated with air emissions. Numerous human-health conditions such as eye irritation and coughing, respiratory problems, cardiovascular disease, neurological, and premature death are associated with exposure to air pollutants. Human-health effects are typically divided into premature deaths and increased rates of illness for valuation purposes.
- *Reduced Agricultural and Forest (Timber) Yields*: Air emissions can negatively affect agricultural yields and timber harvests. Ozone, a secondary pollutant formed by the reaction of VOCs and nitrogen oxides (NOx) in sunlight, can reduce efficiency of photosynthesis reducing agricultural and timber harvest yields.
- *Visibility Costs*: Costs associated with visibility are generally aesthetic, though poor visibility also negatively affects traffic safety. Costs associated with poor visibility have been estimated by measuring for differences in housing prices in areas with varying levels of visibility, holding other housing and location attributes constant.[2]
- *Ecosystem/Environmental Costs*: Environmental damage to plant life and species, not related to agriculture is due primarily to the interference of ozone with photosynthesis, leaving plant life more susceptible to diseases, insects, and other damage. Reduction in forest growth and plant life can impact species diversity in ecosystems.
- *Other Damages*: Other types of damages associated with air emissions include damage to buildings, paint, and other infrastructure requiring increased maintenance costs due to corrosion or other physical damage from air emissions.
- *Global Climate Change*: The primary impacts of climate change include higher temperatures, rising sea levels, and weather variability. The net damages, or costs, associated with climate change are due to changes in agricultural yields, human health (again a major cost category, which includes the spread of tropical diseases), property damage due to flooding, and damage to ecosystems.

The damage function approach used to calculate the cost of emissions is implemented by researchers in integrated assessment models. Integrated assessment models contain both the physical models of the emissions and damages and also the economic models for valuation. The physical models of dispersion, meteorology, and the atmospheric chemistry determine the changes in ambient air concentrations from the emission of an additional unit of pollutant. Epidemiological, clinical, or animal laboratory studies on the physical effects of exposure to air pollution are used to develop exposure-response functions, which describe the relationship between exposure to an airborne pollutant and a particular health (or other) effect. For example, one exposure-response function might describe the relationship between chronic exposure to fine particulate matter (PM2.5) and the rate of adult mortality.[3]

[1] Delucchi, M.A. (2000). Environmental externalities of motor vehicle us in the US. *Journal of Transport Economics and Policy 34*, 135-168.

[2] Delucchi, M. A., J. J. Murphy, and D. R. McCubbin. (2002). The health and visibility costs of air pollution: a comparison of estimation methods. Journal of Environmental Management 64, 139-152.

Once the physical effects associated with air pollution exposure are quantified they are assigned a dollar value. Cost of illness associated with air emissions includes the valuation for chronic asthma, chronic bronchitis, and other costs of illness (medical expense plus lost wages).[4] Estimates of the value of a statistical life have been developed from revealed preference studies of purchase of products that reduce safety risks (e.g., bike helmets) and also through studies on the wage premium in dangerous occupations. Hedonic wage models have also been used to determine the wage-risk premium, or the additional wages per increase in the occupational death rate (risk), to calculate the implied value of a statistical life (VSL). For example, one literature review of hedonic wage models (Mrozek and Taylor) found that an additional $200 per year in wages is required for an additional 1/10,000 risk of death,[5] implying a VSL of $1.5 to $2 million (1998 dollars). A 2003 literature review by Aldy and Viscusi found higher estimates of the VSL, with a median value of $7 million (2000$).[6]

Hedonic price analysis has also been used in the context of property values for valuation of the cost of visibility degradation and air quality. Hedonic price analysis studies compare property values, controlling for housing attributes, income, and other characteristics to determine the implicit price of per unit reductions in the level of total suspended particles in the air for that locality. Stated preference surveys are another method that has been used to determine the value people place on visibility, especially as associated with recreational and scenic areas. Using estimates of the costs associated with visibility in addition to health costs of pollution can lead to double counting of the costs of air pollution because the suspended particles causing poor visibility are also the primary cause of mortality from air pollution.

Market prices, such as those provided by the U.S. Department of Agriculture crop price data, can be used to estimate the dollar value of damage to agriculture yields. Whereas damage to agricultural yields occurs in the same time period as the generation of vehicle emissions, timber harvests are both affected in the current time period and in future years. The multi-year, future timber harvest loss due to ozone exposure can be determined using formulas to calculate the change in the value of the standing timber in the current year by maximizing the present value of the timber stock.[7]

For some pollutants, exposure-response functions may not be constant and there may also be ambient air pollution thresholds where below a certain threshold the health effects are zero. The latter is true for carbon monoxide, which is not assigned an emissions cost in some analyses because the outdoor ambient air concentrations are too low to have measurable health effects.

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[3] For more on the health effects of air pollution see McCubbin and Delucchi, (1996) The Social Cost of the Health Effects of Motor-Vehicle Air Pollution. UCD-ITS-RR-96-3(11).

[4] The U.S. Dept. Health and Human Services, Health Cost and Utilization Project is one source for data on the cost of illness. Health effects of air emissions disproportionately affect the very young and the elderly. One controversy in the valuation of premature death is whether the same value of a statistical life should be applied to all premature deaths, or whether the damage should be calculated as the loss associated with expected remaining life years. Similarly, low-income populations have lower wage rates and therefore would have lower costs associated with lost work days. USDOT policy is to use the same value of a statistical life, regardless of region (i.e., regions have different incomes), income, or age.

[5] Mrozek, J. R. and L. O. Taylor (2002). What determines the value of life? A meta-analysis, J. Policy Anal. Manage, 21(2), 253–270.

[6] Viscusi, W. K., and J. E. Adly (2003): "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." Journal of Risk and Uncertainty, 27(1), 5-76.

[7] Muller and Mendelsohn's APEEP model uses the Faustmann formula to compare the present value of standing timber under baseline conditions and with an ozone (O3) perturbation.

With other pollutants the change in physical effects per additional unit of emission may increase with ambient air pollutant concentrations.[8] Though nonlinear concentration-response functions exist, researchers have observed that most major cost categories are approximately linear with respect to ambient pollution levels.

The marginal damage due to emissions in urban areas has been found to be higher than in rural areas. Considering all sources of emissions, not just mobile sources, urban areas account for roughly 75 percent of the damages due to air emissions but only 50 percent of the emissions.[9] The disproportionate share of damages is primarily due to the size of the population and resources exposure to the air pollution, and to a lesser extent is due to higher ambient air concentrations and nonlinear damage functions.

Research completed by McCubbin and Delucchi in the mid-to-late-1990s is perhaps the most often cited reference on the cost of motor vehicle emissions. In a series of papers, the authors developed damage curves and estimation of the value for different physical effects for estimating the cost of emissions for the major emissions cost categories: health, agriculture damage, and visibility. The authors developed estimates on the dollar cost per kilogram of criteria pollutants, by U.S. county.[10]

More recently, Muller and Mendelsohn (2009)[11] have also developed source-specific damage estimates for point-sources and mobile (ground sources) for every U.S. county in the 48 contiguous states, based on county specific emissions inventories and population data. Their model contains a simple dispersion model for modeling the effects of atmospheric chemistry on ambient air pollution concentration levels. County-specific resources, such as population and agriculture, are then used with damage functions to determine the costs associated with one additional ton of pollutant generated in each county. This methodology includes attributing the cost of damages from secondary pollutants back to the primary emission. Thus, when applying these marginal cost estimates it is appropriate to only account for primary emissions,because including secondary pollutants will double count those costs.

When setting efficient fees for vehicles, it may not be practical to have highly spatially differentiated rates as vehicles move from one jurisdiction to another. For our efficient fee cost allocation application of the emission fees, we are less concerned with the practicality of actual implementation of an efficient emissions fee than we are with our ability to appropriately calculate emissions fee for the vehicle classes and VMT used in the highway cost allocation model.

Using the county as the geographic region will require VMT at the county level. Historic estimates of county-level VMT for state-owned highways are available from the Oregon Department of Transportation (ODOT) through year 2008. Vehicle class VMT by county can be inferred using estimates of VMT by functional class and county-level data from the Highway Performance Monitoring System (HPMS). Table 3 at the end of this report shows the

[8] Delucchi (1996) Reports 11, 12, and 13. Finds that there is not a strong nonlinear dependency between the per unit cost and ambient pollution levels. Damage functions are linear for most major costs or nearly linear.

[9] Muller and Mendelsohn (2007). Measuring the damages of air pollution in the United States. *Journal of Environmental Economics and Management* 54 (2007):1-14. The authors compare urban and rural areas using emissions from all sources, not just mobile source.

[10] McCubbin and Delucchi (1996). *The Social Cost of the Health Effects of Motor-Vehicle Air Pollution*. Report #11 in the Series: The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data. August 1996. UCD-ITS-RR-96-3(11). University of California, Davis.

[11] Muller and Mendelsohn (2009). Efficient Pollution Regulation: Getting the Prices Right. *American Economic Review* 99:55, 1714-1739.

county estimates of the marginal cost of different emissions for Oregon, as developed by Muller and Mendelsohn.

2.4 Social Cost of Carbon

In the case of greenhouse gas emissions, estimates of the cost of an additional ton of carbon dioxide are also typically produced using integrated assessment models. These models combine the geophysical modeling of climate change with models of economic growth and the future cost of the damage associated with the physical effects of climate change. Climate models determine the relationship between additional output of CO2 and the concentration of CO2 over time. These models also contain relationships between carbon dioxide emissions rates and carbon emissions levels (inventories) with changes in temperatures and sea levels. Economic growth models then estimate the optimal, least-cost emissions reduction path, balancing current expenditures for CO2 reduction with the future expected costs associated with the effects of climate change.

A recently published literature review of 211 estimates of the cost per ton of carbon found that the mean estimates fall around $24 and $35 per metric ton of CO2 (tCO2, in 1995 dollars).[12] In the guidance for the USDOT TIGER grant applications in June 2009, the U.S. Department of Transportation recommended the value of $33/tCO2, the value for the global cost of CO2 emissions used in NHTSA's CAFE regulatory impact analysis. The value of $33/tCO2 (2007 dollars) for the global cost per ton of CO2 was based on the best available peer-reviewed mean estimate from a literature review conducted in 2005. The value of $33/tCO2 was suggested as a placeholder for the TIGER grant application benefit-cost analysis, pending the publication of federal guidance on the value of the social cost of carbon.[13]

In March 2010, federal guidance was published on the estimates for the social cost of carbon that should be used in federal regulatory impact assessments. A U.S. federal interagency working group selected four estimates for the social cost of carbon dioxide ($/tCO2, 2007 dollars): $5, $21, $35, and $65. The first three estimates are based on the mean estimates from integrated assessment models using discount rates of 5 percent, 3 percent, and 2.5 percent, respectively. The value of $65/tCO2 is based on the 95th percentile cost, using a discount rate of 3 percent. The higher value estimate for the per ton cost of CO2 is intended to reflect higher-than-expected costs from

Table 1: Social Cost of Carbon Dioxide, 2010-2050 ($/metric ton, in 2007 dollars)

Year	Discount Rate and Estimate			
	5%	3%	2.5%	3%
	Average	Average	Average	95th percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

Source: Table 15A.1 Social Cost of CO2, 2010-2050, (in 2007 dollars), Appendix 15A. Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.

[12] Tol (2008). The Social Cost of Carbon: Trends, Outliers and Catastrophes. *Economics: The Open-Access, Open-Assessment E-Journal*. Vol. 2 2008-25, August 12, 2008. Tol determined the mean estimate of the social cost of carbon using the Fisher-Tippett mean and the Gauss distribution mean from the 211 published estimates, updating his earlier 2005 paper. The mean value of the social cost of carbon were converted to CO2 by dividing the cost per ton of carbon by the ratio of the molecular weights of CO2 and carbon, 44/12.

[13] Estimates of the cost of carbon are presented as the cost per metric ton of carbon dioxide emissions in this issue paper. The cost per metric ton of carbon dioxide can be converted to the cost per (metric) ton of carbon by multiplying the cost per ton of CO2 by the ratio of the molecular weights of CO2 and carbon, 44/12. A value of $35 per ton of carbon dioxide implies a value of $35 x (44/12) = $128 per ton of carbon emissions.

climate change and also reflects that fact that there is a long right-tail in the distribution of the estimates of cost of CO2. Table 1, taken from the federal guidance on the social cost of carbon, displays the per metric ton cost of CO2 for years 2010 through 2050 for the four different selected estimates.

In the discussion of the current and future value of the cost of carbon, there is often mention of the "climate-policy ramp" or the increase in the cost of carbon over time. The current cost of carbon is relatively modest, compared to the cost of carbon projected in future years. By the middle of this century the cost per ton of CO2 is expected to be more than double the current value, growing at rate of 2 percent to 4 percent per year.[14]

While we observe that the federal guidance provides a range of estimates, there is even wider variation in the published estimates of the cost per ton of carbon. Given that most estimates of the cost of carbon are based on only a dozen or so estimates of the total cost of climate change, and most estimates are developed using similar models of the physical effects of climate change, the wide variation in published estimates on the per ton cost has been found to be due primarily to the choice of discount rate and equity weights.

The costs associated with climate change due to greenhouse gas emissions are global in nature and will occur many decades and centuries in the future.[15] Because the present value of the cost of carbon must address damages that take place many decades in the future, future costs must be discounted to the present value. Studies that use low discount rates produce the highest estimates for the cost per ton of CO2, whereas higher discount rates produce lower estimates of the cost per tCO2.

Because the costs of climate change are global, damages must also be aggregated across countries. Equity weights have been used in some studies to adjust the cost of carbon for differences in the welfare effects that would be experienced across countries with different standards of living. A dollar holds more value in poorer countries, so an equity weighting increases the importance of the damage sustained in less-developed countries. In addition to the differences in the value of a dollar across countries, developing countries are likely to experience higher costs due to climate change because their economies tend to rely on more climate-sensitive industries. Thus, applying equity weights in the aggregation of costs across countries has produced higher estimates of the cost of carbon.

Tol (2008) reviews the existing estimates of the per ton cost of carbon in a meta-analysis of 211 estimates. These 211 estimates are all based on roughly a dozen estimates of the total cost of climate change. Tol (2005) and confirmed in Tol (2008) find that the differences in the per unit estimates are due to discount rate and equity weights. Published estimates are also trending downward, not increasing; the highest estimates are from non-peer reviewed studies and those studies tend to use very low discount rates.

Variation and uncertainty in the cost of carbon arises from several sources, not just the choice of discount rate and equity weights. First, there is general uncertainty in the modeling of global climate change related to the understanding of climate change impacts on temperatures, sea-levels, and weather variability. A second source of uncertainty lies in the ability to account for the local impacts from climate change, particularly local impacts due to weather variability and mitigation efforts. A third

[14] Growth rate in the cost of carbon is 2.4 percent in the NHTSA CAFÉ Final Regulatory Impact Assessment.

[15] Discounting is also necessary in the case of reduced timber harvest, but it is not a source of controversy in the cost of air pollutants given that the time horizon is relatively short compared to the effects of climate change. In the valuation of mortality effects of criteria and air toxins, the value of a statistical life is generally the most contentious item influencing the magnitude of the marginal cost estimates.

source of uncertainty is due to extrapolation of impacts to high temperatures and also the limitations in capturing catastrophic impacts. Finally, there are difficulties in modeling adaptation (e.g., behavioral response, government policies), technological change, and other socioeconomic trends, all of which will affect the magnitude and cost of the damages from climate change.

2.5 Determining the Efficient Fees and Revenues Collected From Each Vehicle Class

To estimate the amount of revenue that would be collected under an efficient emissions fee, one would multiply the per mile charge for each vehicle class, functional class (reflecting average speeds) and county, by VMT for each vehicle class for each county in the state.

The revenue that would be collected from vehicles under an efficient emissions fee scheme is then equal to the amount of emissions damage costs that would be allocated to that vehicle class under the efficient method for highway cost allocation.

2.5.1 Data limitations in determining the emissions fee

Though parameter values and data on emission rates and marginal costs of the emissions are mostly available, there are a few challenges to mapping the county-level and federal vehicle class data to the VMT data available in the highway cost allocation study.

Data limitations and possible approaches for addressing the data limitations include the following:

Per mile emission rates will vary by time of day, air temperature, atmospheric conditions, operating speed, vehicle class, vehicle age, vehicle maintenance, etc. Emissions rates from MOVES2010 can be developed for a specific hour during a month, but those rates would have to be roughly representative of all other hours and months of the year. Alternatively, MOVES allows for time aggregation, but applies default VMT distribution by hour of the day. Similarly, the default MOVES national distributions for vehicle model years (e.g., age) and utilization will be used. After reviewing the MOVES emissions rates for different vehicle types, the most appropriate vehicle type will be matched to the HCAS weight classes.

The marginal damage of criteria emissions are highly location dependent because of the nature of the impacts of the emissions on regional population and resources. This argues for location-specific emission rates and marginal costs. To calculate the revenues from a county-specific emissions fee, VMT by county could be used to determine a weighted average for rural and urban counties. ODOT has estimates of VMT on state owned roadways that can be used to approximate the proportion of VMT by county.

Heavy vehicle idling can be a non-trivial source of air emissions. We lack data on the amount and locations of heavy vehicle idling, which would be necessary to allocate emissions costs from idling to vehicle classes. It is unclear whether idling emissions should be included in the calculation of heavy vehicle emission fees; how to assess those fees by vehicle class and weight class; and how MOVES includes "extended idle" process emissions in the emissions output.

2.5.2 Issues Related to Implementation of an Efficient Emissions Fee

The intent of this paper is to present the recommended methods for the calculation of the efficient emissions fee for the Efficient Fee Highway Cost Allocation Study purposes. It is however, important to discuss the implications of implementation of an efficient emissions fee. In particular, the welfare effects of implementing an average emissions fee rather than differentiate emissions fees that reflect the true marginal cost per mile and any social welfare effects from implementing an emissions fee when emissions are already regulated through vehicle fuel economy standards and vehicle emissions control system mandates.

Because carbon dioxide emissions are directly related to fuel consumption (and CO2 makes up the majority of the emissions fee), an emissions fee could logically be imposed using a per-gallon fuel tax rather than a per-mile charge. A per-mile charge would require knowledge of each vehicle's average fuel economy in determining the cost per mile, which would be cumbersome and difficult to administer. An exception to the implementation of the efficient fee as a per-gallon fuel tax is the efficient emissions fee that would be paid by electric vehicles. Ideally, an efficient emissions fee would be levied at the point of electricity distribution. In that case electric vehicles would pay the equivalent efficient emissions fee as a per KwH charge on their electric bill. Otherwise the average emissions fee based on emissions from electricity generation would need to be assessed as a per-mile charge on electric vehicles.

There are practical difficulties to implementing an emissions fee that represents the true cost of damages associated with emissions, that is a fee that is sensitive to the time of day, ambient conditions, etc., a fee which would necessarily be highly differentiated and vary by time, place, and vehicle. As mentioned in the introduction of this paper, implementing "flatter" emissions fees due to practical limitations on the ability to implement highly-differentiated fees representing the vehicle and context-specific weakens the economic rationale behind charging an efficient emissions fee. If fees cannot be practically set to be variable with the context and/or demand for the offending activity is inelastic, there is little or no welfare gain. On the contrary, the fee simply becomes an additional cost of driving and a decrement to consumer surplus. If, in addition, the revenues are costly to collect and/or disposed of inefficiently, there may be a net welfare loss.

The practical difficulty of levying a context sensitive efficient fee is also complicated by equity considerations and practices. The portions of the vehicle fleet that contribute the vast majority of regional pollution are older and under-maintained vehicles, often associated with ownership by the poor. Some states' vehicle emissions inspection and compliance programs provide exemptions from full compliance or limit remediation spending (on tune ups, etc.). If this practice is carried over to an emissions fee, this dimension of efficient differentiation is lost as well. The paper does not endorse this practice, but because it occurs in practice, it is worth noting the potential reduction in the efficiency of the fee if equity-based adjustments or exemptions accompanied the efficient emissions fee.

To date, most of the progress in emissions reductions has been obtained through vehicle technology regulation and mandates, and those regulations and mandates are likely to continue. Hence, it is worthwhile to discuss the implications of an emissions fee if, simultaneously a (inefficient) new set of regulations is to be imposed.

The Clean Air Act, which mandated reduction in auto emissions of 90 percent was, by the EPA's statement, "designed specifically to remove the automobile from its role as the dominant source of air pollution in urban areas."[16] Because the manufacturing cost of clean air compliance was approximately 10 percent of the price of a new vehicle at that time, on an amortized basis over a vehicle life, in essence, users were paying an in lieu emissions fee. Moreover, because the pollution reduction goal was deemed sufficient to resolve the emissions health externality problem in

[16] "Environmental Protection Agency and Department of Transportation, National Highway Traffic Safety Administration: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule," Federal Register, Vol. 75, No. 88 (May 7, 2010), p. 25

urban areas, it is not clear that using historic data to estimate marginal health impacts, etc. leads to a relevant estimate of these effects given that the decline in the health burden is likely exponential in pollutant levels—i.e., the health effects are non-linearly related to exposure levels.

CAFE standards also have been mandated mainly as emissions reduction mechanisms. The CAFE program, enacted in 1975, required manufacturers in the United States to have average sales-fleet fuel economy of 19 miles per gallon in 1978. The mileage standard increased to 27.5 mpg in 1985. The newly-adopted fuel economy and emission standards or passenger cars, light-duty trucks, and medium-duty passenger vehicles imposed by the EPA and NHTSA raise the standard by nearly 50 percent. This is expected to have a cost to industry of $10.8 billion for model years 2012 to 2016, resulting in increases in average new vehicle prices ranging from $457 per vehicle in FY 2012 to $985 per vehicle in FY 2016.[17] Although higher CAFE standards gradually reduce fuel consumption as the fleet evolves, the overall welfare effect requires balancing the effects comprehensively. When this was done by Penn State economist Andrew Kleit in 2002 (regarding a proposed program similar to current policy) he found a negative welfare impact overall of $26 billion.[18]

Thus, the regulatory setting is such that users already experience welfare losses associated with a regulatory program because users are paying higher vehicle ownership and operation costs through higher amortized capital costs of vehicles on a per mile basis than the benefits they enjoy due to the regulation. Indeed, advocates of regulation of motor vehicle manufacturers have argued that this approach is necessary because the emissions tax approach would not modify vehicle use, fuel consumption and emissions sufficiently. Unfortunately, it is not clear that levying marginal cost-based measures of emissions impacts improves social welfare in a potentially (over) regulated setting.

[17] Ibid. p. 324.

[18] Kleit, A. N. (2002) “CAFE Changes, By the Numbers, Regulation, Fall 2002.

Issue Paper 5:

Possible Additional Efficient Fee Components

Jonathan Skolnik, Jack Faucett Associates

1.0 Introduction

The efficient fee approach is based on the idea that every vehicle should pay a per-mile charge that is equal to the costs the vehicle imposes in that mile. That charge will vary with the time and place the vehicle operates as well as with the attributes of the vehicle.

The approach consists of several components:

- A congestion charge component recovers the future costs associated with investing in additional capacity or otherwise relieving congestion. It reflects the costs a vehicle imposes on other vehicles by taking up space on a particular facility.
- A wear-and-tear charge component recovers the future maintenance, preservation, and capital replacement costs that a vehicle imposes by wearing out the roadway.
- An emissions charge component recovers 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.
- An overhead charge component recovers the cost of highway agency activities not directly related to the activities covered by the congestion or wear-and-tear charges, such as planning, administration, human resources, and information services.

Once the appropriate levels for the efficient fees have been determined, the analysis calculates the amount of fees that each user class would pay.

The costs associated with congestion and emissions are both examples of costs imposed on society, and not necessarily borne by the private user in their entirety. Components representing charges for other externalities imposed by vehicles could be included in the efficient fee approach as well. To be included, the externality must be quantifiable, there must be a defined relationship between the quantity of travel and the quantity produced of the externality, and there must be a defined cost (which may be negative in the case of an external benefit) per unit of externality.

Potential externalities include the following:

- Noise
- Water pollution
- Fish passage
- Other environmental effects (e.g., habitat loss)
- Aesthetics
- Accidents
- Energy security
- Land-use as an externality
- Positive economic externalities (accessibility, economic development, and productivity)

This paper identifies and describes many of the potential categories of external costs and benefits. The primary purpose of this paper is to provide information to the Study Review Team (SRT) for the Oregon Highway Cost Allocation study (OHCAS), as opposed to conducting new or original research. Limited information on costs is also included, although additional data are available. Developing this data is a substantial undertaking and beyond the scope of this paper. It will also be important to develop this data for the different classes of vehicles typically examined in the OHCAS.

2.0 Marginal Cost Versus Average or Abatement Cost

In the efficient fee approach, every vehicle will pay a per mile charge that is equal to the costs it imposes in that mile, referred to as the marginal cost. In that manner, each vehicle operator will pay an amount for each mile of travel that is exactly equal to the sum of the costs the operator is imposing. Because the charge is equal to the costs imposed, the vehicle operator will travel only when the benefit they realize from their travel is equal to or greater than the true social cost of their travel. "In the case of transportation, optimal user charges should be equal to the value of the resources consumed through the use of transportation facilities. For example, for road users, prices charged should consist of the damage done to the road surface (variable road maintenance costs) and the additional costs (mainly congestion costs) each user imposes on other users and the rest of society."[1]

Highway departments often address the negative effects of externalities through mitigation expenditures. Some of the mitigation expenditures in Oregon include salmon passage and watersheds, historic preservation, and scenic or beautification projects (aesthetics). These mitigation costs can be allocated to vehicles, however, the amount of current or total spending on an externality may be more or less than the costs to society related to that externality. It is therefore important not to confuse the efficient fee to cover the costs of externalities with current mitigation expenditures. While the Oregon Department of Transportation (ODOT) may have a salmon passage budget, the amount spent per vehicle mile traveled (VMT) may be more or less than the value of the potential habitat loss caused by the highway system.

An environmental impact such as the effect of roadway runoff on salmon or noise imposed on adjacent properties, is not analogous to the average cost of congestion, for example, because it is not, in the first instance, borne by the user. Hence, if the passage of vehicles causes amplification of damage in proportion to the number of vehicles, an "average cost" charge equal to the economic value of the impact per vehicle is appropriate and would constitute an "efficient fee" for that non-user effect.

If the costs of abating the impact are less than the economic impact, that simply means that charging a fee increment that exceeds the average cost of abatement would be inefficient unless the excess were returned to the payor. This is because the cost to society is the lesser of either the impact or the cost of its abatement. Conversely, if the cost of abatement exceeds the economic impact of the externality, then abatement–with or without a fee–is economically inefficient policy. A fee equal to the economic impact imposed should be charged in either case to efficiently influence behavior, but spending on abatement should not exceed the value of the abated impact, and fees collected in excess of the cost of abatement should be returned in some non-distortionary way to the payers.

3.0 Quantification Issues

One important criterion for the inclusion of an externality in the calculation of an efficient fee is the ability to quantify the contribution to marginal cost. Table 1 provides an assessment of the quality of available estimates of external costs by transport mode and cost category developed by Delucchi and McCubbin. Overall, the

[1] Ozbay, K, B. Bartin, J. Berechman (2001). "Estimation and Evaluation of Full Marginal Costs of Highway Transportation in New Jersey." Journal of Transportation and Statistics, Bureau Of Transportation Statistics, United States Department Of Transportation, 4(1), ISSN 1094-8848.

Table 1: Quality of Estimates of External Costs by Transport Mode and Cost Category

	Road		Rail		Air		Water	
	Pass.	*Freight*	*Pass.*	*Freight*	*Pass.*	*Freight*	*Pass.*	*Freight*
Congestion delay	good	good	poor	poor	poor	n.e.	n.e.	n.e.
Accident	good	good	n.e.	poor	poor	n.e.	n.e.	n.e.
Air pollution, health	good	good	fair	fair	fair	fair	fair	fair
Air pollution, other	good	good	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.
Climate change	good	good	good	good	fair	fair	fair	good
Noise	good	good	poor	poor	fair	n.e.	n.e.	n.e.
Water pollution	poor	poor	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.
Energy security	fair	fair	fair	fair	fair	n.e.	n.e.	fair

Pass. = passenger; n.e. = not estimated.

Source: External Costs of Transport in the U.S., by Mark Delucchi and Don McCubbin, Institute of Transportation Studies University of California, Davis, Forthcoming in Handbook of Transport Economics, ed. by A. de Palma, R. Lindsey, E. Quinet, and R. Vickerman, Edward Elgar Publishing Ltd. (2010).

estimates for road transportation are more available and of better quality than for other modes. In the author's judgments, estimates for water pollution and energy security are inferior to the other estimates of external costs.

The following subsections describe each potential externality, including a discussion of why each would be appropriate for inclusion in an efficient fee analysis.

4.0 Noise

Noise can disturb sleep, disrupt activities, hinder work, impede learning, and cause stress. As a result, noise is one reason homes near roadways have less value than similar homes farther away. The external cost of noise from transport includes the value of the damages from excess noise plus the cost of defensive actions or avoidance behavior. Most studies focus on the damages from excess noise. The calculation of these damages requires a model of noise generation from the source, a method for estimating exposure to the noise, and a method for valuing the damages of exposure above a threshold.[2]

A hedonic price analysis can estimate noise damage because noise is a prominent-enough problem that it measurably affects the value of homes. Econometric or hedonic price analyses measure this effect by estimating the sales price of a house as a function of a number of important characteristics, including the ambient noise level or distance from a major noise source. If such an analysis does not omit important determinants of sales price, it can tell us how much an additional decibel of noise (above a certain threshold) reduces the value of a home. This reduction in value per decibel, multiplied by the average value of homes, the number of homes exposed to noise above a threshold, and the amount of noise above a threshold, will tell us the

[2] For example, see Miedema and Oudshoorn (2001) for a review of models of annoyance due to exposure to noise from road, air, and rail transport, and Delucchi and Shi-Lang (1998) for an application of noise-generation models to road noise and the resultant damages.

[3] For a comprehensive discussion of issues in hedonic property value studies of noise from aircraft and road traffic, see Nelson, J. P. (2008). Hedonic Property Value Studies of Transportation Noise: Aircraft and Road Traffic. In A. Baranzini, J. Ramirez, C. Schaerer, and P. Thalmann (eds), Hedonic Methods in Housing Markets, Springer, pp. 57-82.

external "damage cost" of transport noise in and around the home.[3]

5.0 Water Pollution

Fuels and chemicals from transportation modes can spill and leak into oceans, rivers, lakes, and groundwater. This water pollution can harm human health, injure and kill wildlife, corrode materials, and despoil scenic recreation areas. Transportation modes also can cause water pollution indirectly: emissions of nitrogen oxide from fuel combustion can eventually deposit as nitrate and cause nitrogen pollution in aquatic systems. In general, there has been much less research on the dollar cost of the impacts of water pollution than on the dollar cost of the impacts of air pollution. A few studies have quantified the economic cost of oil spills, but there is essentially no systematic research on the costs of the other impacts of water pollution. According to Delucchi and McCubbin, quantifying the cost of water pollution is a relatively low priority because it appears small compared to the other external costs of transport.[4]

6.0 Fish Passage

A related external cost in Oregon is related to fish passage as these provisions add a lot of cost to projects that have to go across streams. As with other external costs, there are both the costs of defensive actions as well as the value of the damages. For example, the 2009 traditional Oregon highway cost allocation study (OHCAS) allocates defensive action costs for "Fish and wildlife enabling projects (e.g., salmon culverts)" based on all VMT. For the 2001 OHCAS, the study review team (SRT) discussed the requirement for special culvert construction allowing fish to pass unobstructed across the highway right-of-way. This is a case where society has identified the loss of certain fisheries as a social cost. By altering highway design specifications, this social cost is mitigated. Highway construction costs are increased and this increase is appropriately allocated to users. Because this social cost is not altered by specific vehicle characteristics, the OHCAS theorized that costs could be allocated by road use (VMT). However, if the mitigation costs are affected by specific vehicle characteristics such as weight, it should be allocated to the classes that occasioned the higher cost. Estimates of damages could also be calculated where salmon culverts are not available or are inadequate.

7.0 Other Environmental Effects (e.g., Habitat Loss)

Transportation infrastructure can also fragment sensitive environmental habitat and thereby disturb and possibly even eliminate plants and other (non-human) animals. Four kinds of fragmentation include destruction, disturbance, barrier action, and collisions with vehicles.[5] Valuing these impacts is a complex undertaking. Delucchi and McCubbin suggest the work of Nijkamp et al. for a review of issues in estimating the economic value of biodiversity.[6] Willis reviews studies of the "wildlife value" and "landscape value" of land used for roads in Britain. They report a very wide range of values, from less than £10/ha/yr to more than £10,000/ha/yr, depending, naturally, on the type of land

[4] Delucchi, M. and D. McCubbin (2010). External Costs of Transport in the U.S., Institute of Transportation Studies University of California, Davis, Forthcoming in Handbook of Transport Economics, ed. by A. de Palma, R. Lindsey, E. Quinet, and R. Vickerman, Edward Elgar Publishing Ltd. p. 19.

[5] Van Bohemen, H. D. (1995). Mitigation and Compensation of Habitat Fragmentation Caused by Roads: Strategy, Objectives, and Practical Measures. Transportation Research Record, No. 1475, pp. 133-137.

[6] Nijkamp, P., G. Vindigni, and P. A. Nunes (2008). Economic valuation of biodiversity: A comparative study. Ecological Economics, 67, 217-231.

[7] Willis, K. G., G. D. Garrod, and D. R. Harvey (1998). A Review of Cost-Benefit Analysis as Applied to the Evaluation of New Road Proposals in the U. K., Transportation Research D, 3, 141-156.

(forest, meadow, farm, etc.), and the type of values solicited (use value, option value, existence value, etc.).[7]

8.0 Aesthetics

All modes create unsightly infrastructure and waste, which presumably have an aesthetic cost. For example, surveys have found that the public feels that the world would be prettier without roads.[8] The courts have formally condemned the unsightliness of scrapped autos and junkyards.[9]

9.0 Accidents

The costs of accidents include medical costs, property damage, lost productivity, insurance administration, emergency services, and the non-monetary costs of lost quality of life and pain and suffering because of death and serious injury. The threat of motor vehicle accidents also gives rise to "fear and avoidance costs" – for example, the opportunity costs of making people afraid to walk—and "extra attentiveness costs" (i.e., extra effort to avoid accidents). Insurance is intended to cover most of the direct costs of accidents, though insurance does not compensate non-roadway users for some of the aforementioned costs.

Although estimating the total costs of accidents can be relatively straightforward, it is more challenging to estimate the value of non-monetary impacts such as pain and suffering and lost quality of life, although there is a large body of literature on this subject. Further yet, modeling the costs that are imposed on society separate from the private costs borne by drivers is not only challenging, but little research has been conducted in this area.

Parry (2004) developed an analytical model to separate accident costs into the private and non-motorist (external societal) costs. The results of the model suggest that the external costs vary much more across driver groups (e.g., age groups, risky-driving factors) than across the light vehicle classes, although passenger pick-up trucks do have higher external costs (external costs for pick-up trucks are about 31 percent higher than the average).[10] On a per-mile basis, Parry finds that the external costs of accidents ranges from 3 to 11 cents per mile depending on the vehicle group or driver group (minivans have the lowest cost while drivers under the age of 25 have the highest).

The discussion of accident costs requires some consideration of risk and insurance effects. Association of accident rates to ambient traffic conditions has proved an elusive exercise and, in any case, accidents are random events drawn from extreme value distributions. Thus, mathematical notions of average and marginal costs are difficult to operationalize for the purpose of constructing accident fee increments. More importantly, however, to the extent that drivers carry insurance, they face very steep marginal fees for causing a material accident because of high deductibles, the risk of premium increases and/or the total loss of coverage. To the extent that insurance compensates the driver, injured third parties and property owners, it is hard to make the claim that accidents impose uncompensated externalities on these parties. To the extent that public services, such as police and fire services, bear an uncompensated burden from dealing with accidents, of course, these would be externalities in the traditional sense and could justify a fee increment. The increments estimated in Parry (2004),

[8] Huddart, L. (1978). An Evaluation of the Visual Impact of Rural Roads and Traffic. Supplementary Report 355, Transport and Road Research Laboratory, Crowthorne, England.

[9] Woodbury, S. (1987). Aesthetic Nuisance: The Time Has Come to Recognize It. Natural Resources Journal, 27, 877-886.

[10] Parry, I. W. H. (2004). Comparing alternative policies to reduce traffic accidents, Journal of Urban Economics 56, 346-58.

however, seem far too large, given the portion of accident costs that is already borne by drivers through insurance.

The largest externality that accidents impose is on the traffic stream, in the form of in- creased travel times (travel delay) or disturbed departure schedules (schedule delay). However, traffic models employ empirical speed-flow and volume-delay representations that implicitly incorporate at least the former type of delay to some degree. Hence, to add an accident increment based on this manifestation of accident impacts would be a double-count to a large, but unknown degree. To the extent that travelers' schedules are interrupted or they schedule trips in a non-optimal way in order to partially offset the risk of accident-related schedule delay, a true externality may exist. Even here, however, if accidents are purely random events, there is no efficiency effect obtained by levying a fee for accidents' impact on schedule delay costs because (by assumption) no consumer response is possible. Additionally, if there is a non-random component to accidents (e.g., accidents occur with greater frequency or severity under congested conditions), congestion charges calculated from volume-delay relationships estimated in the presence of accidents might be argued to be sufficient to capture this externality.

Based on the per-mile cost estimates from Parry, external accident costs may be a large external cost that should be included in the efficient fee study. However, research on the external costs of accidents has only been conducted for passenger vehicle types, external accident costs based on vehicle weight or for large trucks could not be found in the literature. Large trucks due to their size and weight are often involved in more severe accidents, however large trucks have lower accident rates. Given that the per-mile external costs of accidents are not available for large trucks, accident costs will not be included in the current efficient fee study, but may be included in future studies when data on the external costs of accidents for large trucks is available.

10.0 Oil/Energy-Related Externalities

The United States consumes about one fourth of the world's petroleum, and imports nearly 60 percent of its own consumption.[11] More than two-thirds of U.S. oil consumption goes to the transportation sector. The heavy use of imported oil by the transportation sector gives rise to several kinds of economic costs not reflected in the price of oil: the cost of the Strategic Petroleum Reserve, defense expenditures to protect U.S. oil interests, macroeconomic disruption/adjustment costs due to price volatility and supply disruption, and wealth transfers from U.S. consumers to foreign producers. These external costs ultimately derive from the concentration of large amounts of oil in relatively unstable regions of the world, in particular the Persian Gulf. "One conceptual difficulty with it is that a main component results from OPEC's monopoly power; the "premium" calculated is not really an external cost and is not appropriately handled by charging a fee, since the problem is that the price is already inefficiently high. Another conceptual difficulty is that other costs, especially climate change, are global in scope, whereas the energy security "premium" is usually calculated

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[11] Davis, S. C., S. W. Diegel, and R. G. Bundy (2008). Transportation Energy Data Book, ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[12] Comment received from Kenneth Small, Oregon Highway Cost Allocation Study Expert.

[13] NHTSA, USDOT. (2009). Corporate Average Fuel Economy for MY2011 Passenger Cars and Light Trucks. Final Regulatory Analysis. March 2009. Office of Regulatory Analysis and Evaluation, National Center for Statistics and Analysis.

specifically for the U.S. and for part of it, the loss to the U.S. is a gain to oil-exporting countries."[12] The NHTSA Corporate Average Fuel Economy (CAFE) Final Rule Making for MY2011 did not include defense-related costs of oil since theoretically, the United States would continue to rely on oil for many other industrial sectors and military sectors would not necessarily decrease due to changes in fuel consumption in the transportation sector at the margin.[13]

11.0 Land-Use as an Externality

Poorly designed and thoughtlessly placed transportation infrastructure can divide communities, impede circulation, and create barriers to social interaction. On the other hand, transportation facilities, particularly roads are crucial to economic activity and trade and provide people with access to locations, with those travel benefits capitalized in the site values.

The negative land-use externalities may have been one source of the "freeway revolts" that began in the late 1960s and shut down freeway projects in several U.S. cities were spawned in part by negative social impacts. The dead-end Embarcadero Freeway in San Francisco, torn down after the 1989 Loma Prieta earthquake, is perhaps the most famous example. Soguel cites a study by Appleyard that shows that "residents of San Francisco with light volumes of traffic have three times as many local friends and twice as many acquaintances as those on heavily traveled streets."[14] In recent years, sprawl along with loss of farmland and rural areas has become a major issue and many observers categorize these effects as negative land use externalities of our transportation system.

While there are negative land use externalities, like those above are cited, particularly with respect to freeways and some types of roadway designs, roadways can also increase land values, providing a positive land use externality. More generally, the capitalization hypothesis states that the value of public goods, namely public infrastructure or public services, is capitalized into land rents or site values given preferences for those public goods. Given the manifestation of transportation benefits in land values, rather than vice versa, it is difficult to determine whether the resulting pattern of development is dominated by negative externalities (on balance) given the characteristics of the transportation facilities and transportation improvement projects. The recent paper by Ewing and Cervero (2010)[15] seems to confirm that the causality runs from the transportation system to the built environment, rather than vice versa. Indeed, they conclude: "travel variables are generally inelastic with respect to change in measures of the built environment."

Conceptually, it seems possible to conduct a study of the land-use externalities due to roadways, however these costs are beyond the current knowledge and research and there are benefits in addition to the costs, so research would need to determine the net effect of transportation on land values.

12.0 Accessibility, Economic Development, and Productivity Benefits

Although the majority of literature focuses on the external costs of transportation, the transportation system potentially provides a variety of external benefits in terms of accessibility, economic activity, economic development, and productivity. Indeed, many transportation

[14] Soguel, N. C. (1995). "Costing the Traffic Barrier Effect: A Contingent Valuation Survey." Environmental and Resource Economics, 6, 301-308.

[15] Ewing, R. and Cervero, R. "Travel and the Built Environment: A Meta-Analysis," Journal of the American Planning Association, Vol. 76, No. 3, Summer 2010

improvements are often motivated by goals of retaining or stimulating economic activity. While there may be positive network externalities and economies of agglomeration, the issue of positive externalities is complicated by the risk of double-counting benefits. Additionally, it is unclear whether certain vehicle classes produce more external benefits than others and how to allocate such benefits.

A report to the Federal Highway Administration notes, "Although the existence of positive network externalities remains a matter of debate in transportation circles, their quantitative significance is not doubted in related fields, such as telecommunications."[16] Authors such as Capello and Rietveld make a compelling argument for government policy as a means of correcting for an under-supply of highway infrastructure because of the existence of positive network externalities. The authors argue that logistics-oriented telecommunications systems are characterized by positive externalities in the adoption process. Given the high fixed costs of acquisition, government policy might be justified in order to ensure the economically optimal critical mass of users.

In the telecommunications arena, positive network externalities arise because other users of the phone system benefit if others are on the same network, thereby reducing exponentially the cost of communicating among businesses and households. If an analogous externality exists in roadway networks, then there should be economic growth effects of highway activity manifest in macroeconomic growth measures.

Economies of agglomeration refer to the external benefits generated from the ability of businesses and activities to locate in closer proximity, increasing the interaction of experienced firms, and reducing costs.[17] Large productivity gains have been estimated from the building of the U.S. Interstate Highway System however, the incremental improvements made to developed systems have less of an effect than in less-developed systems or countries.[18]

The literature does seem to support this notion of positive network externalities, although available data and specification issues can never be fully dispositive. One type of study links highway investment activity with post-construction employment growth, such as the study by Jiwattanakulpaisarn et al (2006).[19] Another approach is that pursued by Pozdena (2009) [20] and Liddle (2010),[21] using time-series cointegration and vector autoregression

[16] Freight Benefit/Cost Study: Compilation of the Literature, Final Report, Presented to the Federal Highway Administration, Office of Freight Management and Operations, Presented by the AECOM Team, February 9, 2001, Section 3-3-3 Benefit/Cost Analysis. See http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/comp_lit/sec_3.htm

[17] Two good studies of agglomeration benefits of transportation are:

Graham, D. J. (2007). "Agglomeration, Productivity and Transport Investment," Journal of Transport Economics and Policy, 41, 2007: 317-343.

Graham, D. J. (2007) "Variable returns to agglomeration and the effect of road traffic congestion," Journal of Urban Economics, 62, 2007: 103-120.

[18] Fernald, J. (1999). "Roads to prosperity? Assessing the link between public capital and productivity," American Economic Review 89: 619-38.

[19] Jiwattanakulpaisarn, P., Noland, R.B., Graham, D.J. Polak, J.W. (2006). "Highway Infrastructure Investment and Regional Employment Growth: A Dynamic Panel Regression Analysis," paper submitted to the 46th Congress of the European Regional Science Association (ERSA).

[20] Pozdena, R. "Vehicle Miles Traveled and the Economy The Challenge for Climate Policy," Research Paper prepared by QuantEcon, Inc., for the BiPartisan Center of the US Congress, July 2009.

[21] Liddle, B. "Long-run and short-run elasticities for gasoline demand in OECD countries: A panel cointegration approach," Working Paper October 2010.

(VAR) models incorporating VMT as the measure of highway activity. All three of these papers attempt to isolate the causal relationship (rather than simple association) between highway activity and economic activity. All three appear to support the notion that highway investment and use have positive, causal economic growth impacts.

Other examples point to positive externalities in vertically integrated sectors where improvements for shippers in forward markets generate unpriced advantages for shippers in backward-linked markets. Government policy might be able to exploit such positive spillovers with policies that accelerate the take-up of advanced logistics in forward markets. For example, HLB (for the American Trucking Foundation), found that even small positive network externalities per truck-mile could add up to an aggregate sum as large as the negative congestion externalities attributed to heavy trucks. HDR/HLB constructed a tool for state and local entities to estimate additional benefits derived though logistics rearrangements from highway performance improvements.[22]

Blum has argued that "The general discussion on externalities of transportation—be they monetary or technological—usually concentrates on negative effects . . . we concentrate on positive effects, although most scholars would question their existence—and in most cases they are right if the external effect is defined purely on a technological basis, leaving out monetary effects." His paper notes "that while direct, technological, external benefits from transportation are difficult to find, meaningful positive externalities can arise from transportation systems in at least two ways. First, transportation infrastructure can reduce preexisting negative externalities. Second, because transportation is essentially a derived demand its effects diffuse throughout the primary markets that induce transportation demand. To the extent that changes in transportation infrastructure induce positive externalities in these primary markets, external benefits should be attributed to transportation."[23]

To the extent that there is a causal relationship between VMT and economic growth, this raises the interesting issue of whether a negative fee (i.e., a per VMT subsidy) could be justified on the grounds that there is a positive social externality to vehicle use. The low short-run elasticity of VMT with respect to fuel prices (the closest proxy to a fee's impact) observed by Pozdena (2009) suggest that a relatively large subsidy per VMT would be necessary to stimulate economic growth, but such a large fee may be justified if the economic benefits of growth are perceived as large.

13.0 Available Cost Data

Table 2 provides a summary of some external cost estimates collected by Delucchi and McCubbin. Note that for passenger vehicles, available estimates place accident costs at the high end of external costs. At the higher end of the range of estimates, noise is also significant. Energy security imposes smaller but significant external costs, whereas water pollution is relatively insignificant. For freight, which is on a ton-mile basis, accident costs are less significant, perhaps reflecting lower crash rates of large trucks.

[22] FHWA. (2008). Freight Benefit/Cost Study: Highway Freight Logistics Reorganization Benefits - Estimation Tool Report and Documentation, FHWA –HOP-08-017, Prepared by: HDR|HLB Decision Economics Inc. for the Federal Highway Administration, Office of Freight Management and Operations, February, 2008.

[23] Blum, U. (1998, October). "Positive Externalities and the Public Provision of Transportation Infrastructure: An Evolutionary Perspective." Dresden University of Technology, Journal of Transportation and Statistics, 81-88.

14.0 Summary and Conclusions

An efficient fee will reflect a summation of the full cost of traveling an additional mile. This will provide incentive for a driver to travel that mileage only if the benefit realized for travel of that last mile exceeds the costs to society for that last mile, the definition of an efficient fee. This paper discussed several categories of external costs associated with highways and road use.

Issue Paper 6:

Current Issues in Pavement Cost Allocation

Roger Mingo, Roger Mingo and Associates

1.0 Introduction

The National Pavement Cost Model (NAPCOM) first emerged from the pavement distress models developed for the 1982 Federal Highway Cost Allocation Study (HCAS). From its inception, NAPCOM has strived to accurately describe how pavement costs vary as a function of vehicle use. To that end, it has always tried to include and incorporate the most proven and accepted pavement damage models and theories.

Before the 1982 Federal HCAS, highway cost allocation studies had used the results of the 1950's-era AASHO Road Test to determine the relative responsibility of vehicle classes for pavement costs. The Road Test subjected thin pavement sections to repeated applications of axles of various weights and originated the concept of equivalent single-axle loads (ESALs)—measures of the relative impacts of axles of various weights that varied roughly with the fourth power of axle weight.

By the time of the 1979 to 1982 federal study, advances in pavement engineering had increased the awareness that pavement deterioration was much more complex than could be expressed by a single measure. Pavement deterioration could be measured by various "distresses" (such as rutting, transverse cracking, or roughness). Some of these distresses might vary with the fourth power of axle weight whereas others might vary with only the first or second power.

Further, the trucking industry was well aware that a fourth-power assumption might severely overcharge them if used to allocate pavement cost responsibility. As a result of the high visibility and potential high stakes of making assumptions about pavement deterioration, the Federal Highway Administration (FHWA) devoted considerable effort to incorporating the best then-available knowledge in more precisely quantifying pavement cost responsibility, and developed a set of empirically based pavement performance models for estimating cost responsibilities.

The 1982 models were updated later in the 1980s with the initial development of NAPCOM. For their 1995 HCAS, FHWA updated several of the NAPCOM distress models using mechanistic-empirical pavement damage equations that describe the relationship of axle loads and repetitions to pavement distresses.

The most recent version of NAPCOM includes newly developed distress equations and load equivalency factors (LEFs) based on AASHTO's Mechanistic-Empirical Pavement Design Guide (MEPDG) model. This latest version of NAPCOM has completely revised distress prediction equations and new LEF formulas that are completely independent of ESALs and the fourth-power assumption.

2.0 Overview of NAPCOM$_{2010}$

The new version of NAPCOM deviates from earlier versions in several important ways: (a) for the first time, all LEFs are independent of ESALs, (b) all of the distress and LEF equations in the model derive from the new MEPDG models, (c) NAPCOM now shares distress equations with FHWA's Highway Economic Requirements System (HERS), and (d) NAPCOM's new distress equations are calibrated to pavement distress data collected by the states and reported to FHWA through the Highway Performance Monitoring System (HPMS).

In earlier versions of NAPCOM, flexible damage equations were expressed in terms of axle loads and types, but the rigid distress equations were expressed in terms of ESALs. The flexible models generally followed mechanistic pavement response theory while the rigid models were much more grounded in empirical data—essentially stuck on using ESALs. Because both sets of models now derive from MEPDG models, LEFs are no longer constrained by the fourth-power assumption.

To derive the new LEF equations, we started with representative pavement sections in a variety of climates and with a variety of design and traffic conditions. For each section, we first ran a base case to determine distress levels at the end of a design life (20 years for flexible pavements, 30 years for rigid pavements). We then removed 10% of the base case traffic and systematically added axles of each weight and type (single, tandem, and tridem) to determine for each type of distress how many daily axles of each weight caused precisely the same level of damage as the removed 10% of base case traffic. LEFs were defined as the ratio of the damage per axle load relative to the damage caused by a single 34-kip tandem axle. Appendix A includes example equations and tabulations of typical LEFs, as well as an overview of the derivation of these LEFs.

The overall distress level equations newly developed for use in HERS and NAPCOM, however, do express traffic-related pavement loading in terms of ESALs. These models were developed under contract to FHWA by Applied Research Associates (ARA), developers of the MEPDG, and with Battelle. Over a three-year period, the study team developed a proposed set of distress models that predict pavement distress levels as a function of environmental and design variables as well as accumulated ESALs. In the last year, the team has made a few adjustments to the models, and there may be a few more. NAPCOM will adjust its models as needed to remain consistent with HERS. Appendix B includes descriptions of each of the ARA / Battelle distress equations used in NAPCOM and HERS.

In earlier versions of NAPCOM, the distress models predicted distress levels at the end of each year of analysis. When a pavement section reached a condition that would trigger a need for major rehabilitation or reconstruction, NAPCOM took note of the specific distresses and their contribution to the need to rehabilitate, the contribution of specific groups of vehicles to each of these distresses, and the year of failure. It accumulated these factors by pavement type, highway type, and state.

After all pavement sections within a particular highway class and geographic equation had been analyzed, NAPCOM converted the tabulated arrays of failure data into vehicle cost responsibilities and relative responsibilities per mile. In this way, LEFs for each distress were derived from model runs and would vary somewhat by state and highway type.

The new version of NAPCOM shifts this logic to some degree. First, because HPMS now includes (or soon will include) pavement distress data for each sample highway section, we can adjust the distress models to match each individual pavement section. If, for example, we see that an 8-year-old pavement has twice the rutting that NAPCOM predicts but only 80% of the alligator cracking, we can change the rates of deterioration to better predict the time and condition of the pavement in future years.

Second, we now have LEF equations for each distress, so we do not derive them from the NAPCOM run. We can calculate and accumulate the damage caused by each axle on each pavement section directly from the corresponding LEF equation.

Originally, the supplemental pavement distress information was supposed to have been submitted by the states beginning with this year's (2009) HPMS data. FHWA has now given states the option of waiting until 2010 to provide these data, and Oregon has opted to wait. When any pavement section is missing the supplemental distress data, NAPCOM does not calibrate the damage models to match the observed condition but simply reverts to the old logic—calculating distress levels without calibration.

3.0 Opportunities for Optimizing the Use of NAPCOM$_{2010}$ in Oregon

(a) As with previous versions of NAPCOM, we have to make assumptions about many pavement design parameters not included in the HPMS section data. We could improve the application of the model in Oregon by again working with ODOT pavement engineers to make sure that the assumptions implicit in NAPCOM for national application are accurate assumptions for Oregon (**Recommended**).

(b) The new version of NAPCOM can benefit greatly by including as much current distress information as possible for each pavement section. In fact, it is designed to self-calibrate on each pavement section for which we have distress information. The 2009 Oregon HPMS submittal includes no distress information —only IRI values. We could try to work with ODOT's pavement management engineers to attempt to match pavement management distress data with HPMS sections (**Recommended**).

(c) Skid resistance has been eliminated from NAPCOM in the new version because it was not judged to have significant influence on most rehabilitation decisions. Old NAPCOM included studded tire damage as an implicit part of its skid resistance distress mode, but new NAPCOM has no consideration of studded tier damage. Given the importance of studded tire damage in Oregon, we should work with ODOT's pavement management staff to see if sufficient empirical data are available to adjust NAPCOM's distress models for application in Oregon. If we have sufficient historic data on enough sections, we could attempt to develop an empirical skid resistance model to add as an option in NAPCOM (**Recommended**).

(d) None of the pavement sections used in the development of NAPCOM's new LEF equations was physically located in Oregon. We had pavement sections in Boulder, Colorado, Monterey, California, and Rapid City, South Dakota, all of which may approximate climate in some parts of Oregon, but none of which included specific Oregon design and construction practices. We could add several representative pavement sections in Oregon climates, work with ODOT pavement engineers to replicate ODOT design practices, and develop custom LEFs for Oregon for both rigid and flexible pavements (**Recommended**).

(e) Because all NAPCOM models have changed since the last study, we could compare the results we would get with both the new and old versions of NAPCOM to illustrate how much effect the model changes have on overall study results (**Recommended**).

Appendix A: Load Equivalence Factors (LEFs) Used in NAPCOM

This section illustrates how we derived the new LEF equations for a single typical flexible pavement on a moderately heavily traveled rural primary highway near Rapid City, South Dakota. We first ran the MEPDG program for a base case traffic level of 5000 trucks per day, then for a slightly reduced level of 4500 trucks per day to determine distress levels at the end of a 20-year design life in each case. As shown in Table A-1, each traffic-varying distress modeled by MEPDG showed a small, but measurable, change in 20-year levels.

Table A-1: Distress Levels at 4500 and 5000 Trucks per Day

ADTT	Long Crk	Allig Crk	AC Rut	Total Rut	IRI
4500	2250	7.5	0.336	0.747	135.40
5000	2540	8.4	0.354	0.768	136.70

We then added axles of one size and weight at a time, by modifying the intermediate traffic files of MEPDG, to the 4500-truck-per-day run until we could tell how many added axles of that particular weight and type would cause precisely the same level of each distress as were produced by the 5000 trucks per day.

For example, Table A-2 shows results of the runs we made for 34-kip tandem axles.

Table A-2: Distress Levels with 4500 ADTT and Added 34-Kip Tandem Axles

Axles	Long Crk	Allig Crk	AC Rut	Total Rut	IRI
310	2540	8.1	0.348	0.758	136.10
570	2790	8.5	0.358	0.768	136.80
1000	3180	9.3	0.373	0.784	137.80
10000	7730	23.6	0.608	1.021	156.10

We made our first two runs at 1000 and 10000 added axles and found that all distresses were already too high at even 1000 added axles. We interpolated downward from 1000 axles with two additional runs and got quite close to the target distress levels with the runs of 310 and 570 added axles. Because the distresses varied linearly with axle additions in this range, our interpolated final estimates are likely to be very reliable.

We repeated this process for a series of different axle weights and types. We used single axle weights of 8, 12, 16, 18, 20, 22, 24, 28, 32, 36, and 40 kips; tandem axle weights of 16, 24, 28, 32, 34, 38, 42, 48, 54, 60, 66, 72, and 80 kips; and tridem weights of 24, 30, 36, 45, 51, 60, 72 , 84, 90, 96, and 102 kips. These weights covered the entirely plausible domain of application of the MEPDG model (and then some).

In some cases, we needed to iterate several times to get close to correct target distress levels, because one of the distresses did not consistently vary linearly with number of axles. For example, we had to make 10 runs for 20-kip single axles because we started high and linear interpolation kept over-guessing on the necessary lower number of axles, as shown in Table A-3.

Table A-3: Distress Levels with 4500 ADTT and Added 20-Kip Single Axles

Axles	Long Crk	Allig Crk	AC Rut	Total Rut	IRI
530	2250	8.9	0.351	0.761	136.70
2000	2260	12.6	0.389	0.800	140.30
5000	2280	19.6	0.455	0.868	147.30
10000	2310	29.5	0.548	0.962	158.10
17000	2350	40.3	0.654	1.071	172.30
22000	2380	46.4	0.720	1.138	182.00
28000	2410	52.4	0.791	1.210	193.30
33000	2820	56.5	0.846	1.265	202.70
108000	6950	82.0	1.421	1.847	331.20
200000	8750	89.9	1.890	2.320	479.70

In all, we made 198 runs of the MEPDG model for this one typical flexible pavement section. Table A-4 shows the numbers of added axles of each weight and type that produced the target levels of distresses.

Table A-4: Daily Axles to Target Distress Levels

Weight	Type	Long Crk	Allig Crk	AC Rut	Total Rut	IRI
8	Single	1292857.1	14528.1	4745.5	5800.0	7375.0
12	Single	228846.2	2650.6	1963.6	2400.0	2585.7
16	Single	73529.4	812.5	1063.6	1300.0	1056.2
18	Single	44888.9	506.0	818.2	1000.0	722.2
20	Single	29585.4	331.3	646.1	793.8	530.0
22	Single	17487.2	223.7	533.8	596.2	382.4
24	Single	14222.2	158.1	427.6	448.5	273.7
28	Single	6720.0	85.0	314.3	225.8	144.4
32	Single	4378.6	49.7	236.4	100.0	72.2
36	Single	2654.5	30.9	185.2	46.7	39.0
40	Single	1775.0	20.2	148.6	20.0	20.0
16	Tandem	6900.0	10647.2	2454.5	3000.0	4000.0
24	Tandem	1287.8	1984.6	981.8	1200.0	1425.0
28	Tandem	670.0	1038.7	711.3	876.3	934.0
32	Tandem	390.0	607.8	534.4	650.0	650.0
34	Tandem	310.0	473.9	466.0	570.0	532.9
38	Tandem	193.3	301.8	360.0	422.5	371.4
42	Tandem	130.0	201.3	302.7	305.4	263.0
48	Tandem	74.8	117.5	221.3	164.6	146.7
54	Tandem	46.8	73.0	170.0	75.5	76.7
60	Tandem	31.0	47.8	141.7	34.8	37.3
66	Tandem	21.4	32.7	114.0	16.2	20.2
72	Tandem	15.0	23.1	94.3	8.2	11.0
80	Tandem	9.7	15.1	78.5	3.9	5.5
24	Tridem	2058.1	9883.6	1721.7	2100.0	2931.2
30	Tridem	820.0	3905.0	1055.6	1232.2	1630.8
36	Tridem	377.0	1837.3	697.7	848.3	1058.8
45	Tridem	149.7	736.2	419.3	490.0	575.0
51	Tridem	90.6	441.9	329.0	296.0	337.1
60	Tridem	46.8	228.5	231.0	122.0	140.0
72	Tridem	22.7	109.3	157.8	30.5	44.4
84	Tridem	12.3	58.9	115.7	8.9	13.8
90	Tridem	9.3	44.6	94.7	5.3	8.3
96	Tridem	7.1	34.3	87.1	3.4	5.5
102	Tridem	5.6	26.8	75.8	2.1	3.5

We could calculate LEFs directly from this chart for this pavement section because we define LEF as the amount of damage done compared with the reference load of a 34-kip tandem axle. Because 310 tandem axles weighing 34 kips produce the same longitudinal cracking damage as do 90.6 tridem axles weighing 51 kips, we would say that 51-kip tridems have an LEF of 3.42 for this section. On the other hand, they have an LEF of only 1.08 for alligator cracking.

To make our results more generally applicable, we instead estimated log-linear and log-quadratic fits for each of the LEFs for each pavement section. Through some experimentation, we found we got excellent fist with log-linear regression for longitudinal cracking, alligator cracking, and AC rutting, but we had to use log-quadratic fits for total rutting and IRI. In fact, we had to use dual-range (high and low) quadratic fits for single and tandem axles, but not tridems.

Table A-5 shows the log-linear coefficients we estimated for three distresses for this Rapid City pavement section, and Table A-6 shows the log-quadratic coefficients for the other two distresses:

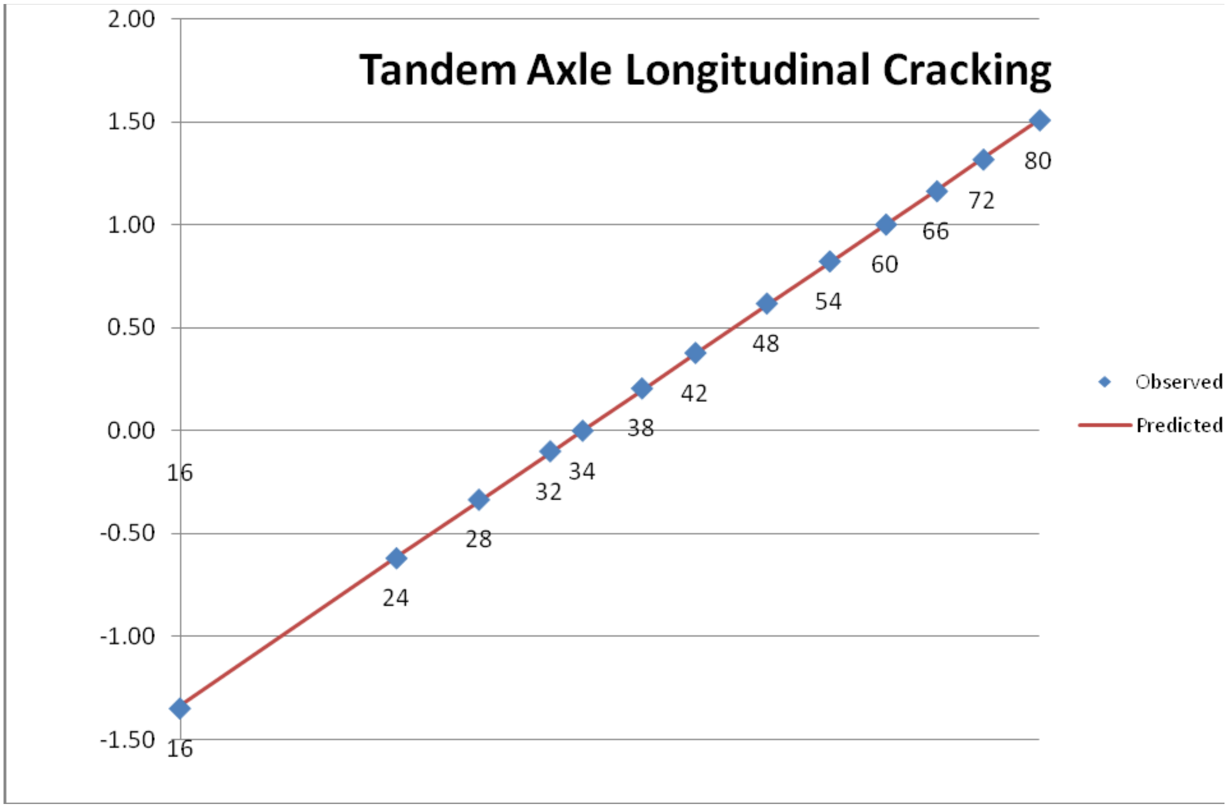
Table A-5: Log Linear Coefficient Estimates

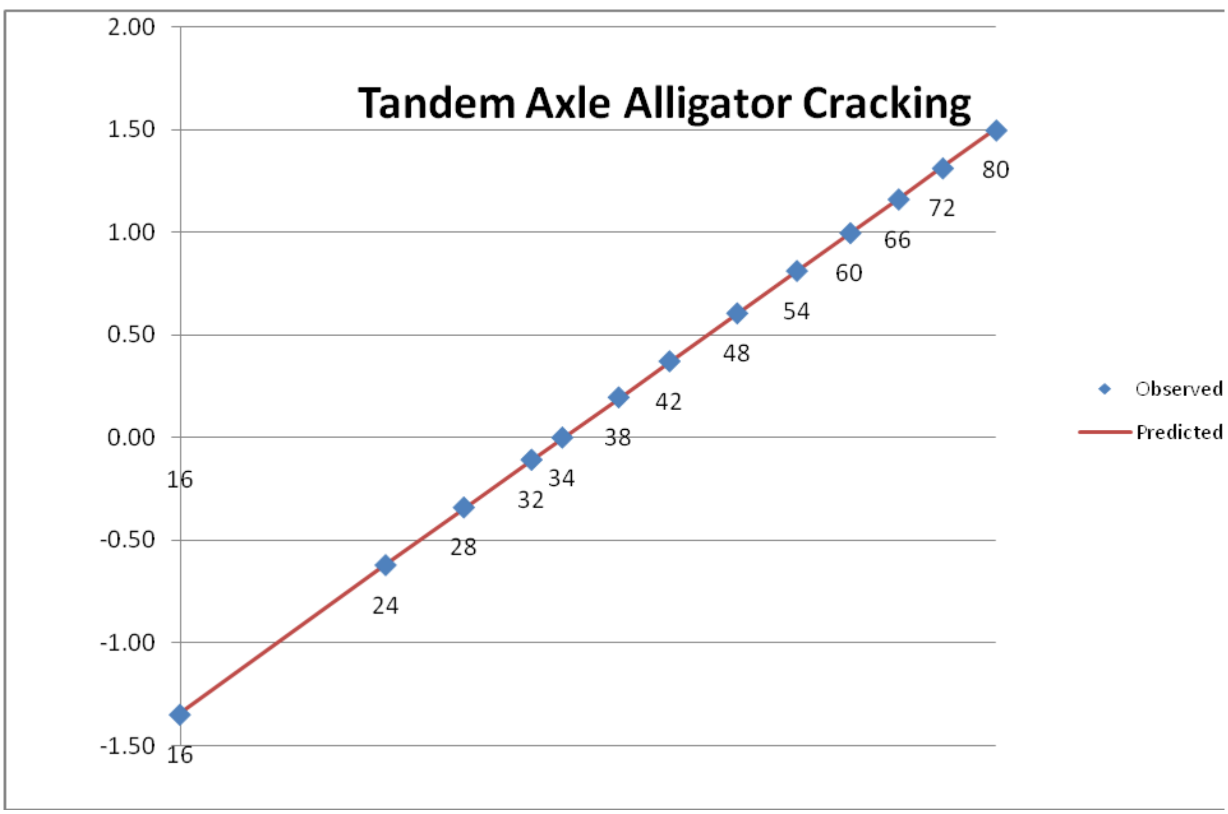
	Long Crk	Allig Crk	AC Rut
Sing Slope	4.099	4.074	2.157
Intercept	-7.303	-5.149	-2.952
Tand Slope	4.066	4.064	2.141
Intercept	-6.228	-6.230	-3.284
Trid Slope	4.074	4.075	2.154
Intercept	-6.432	-6.935	-3.531

Table A-6: Log Quadratic Coefficient Estimates

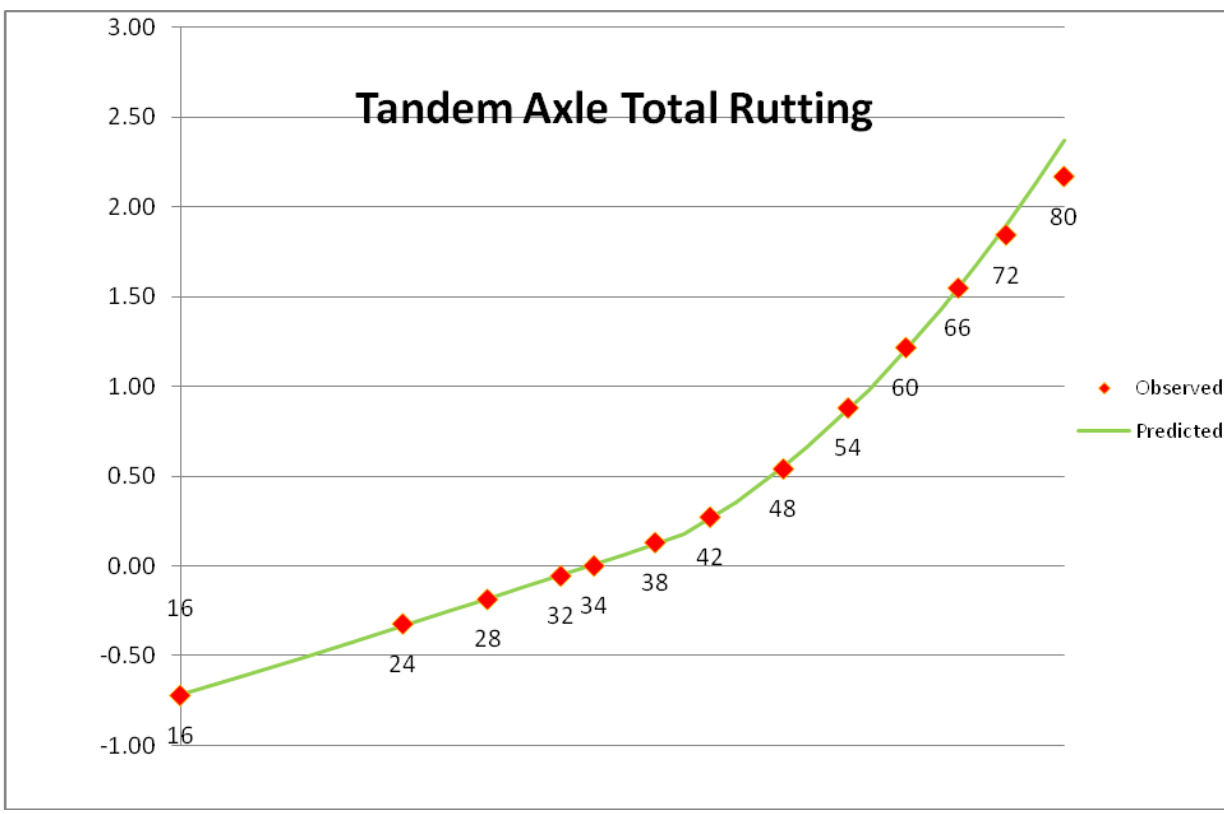
	Low Rutting Quadratic		
Sing Slope	0.820	0.401	-2.032
Intercept	0.330	0.755	0.424
Tand Slope	0.239	1.571	-2.956
Intercept	0.305	0.847	0.583
Trid Slope	7.095	-19.298	12.612
Intercept	0.530	1.817	1.539
	High Rutting Quadratic		
Sing Slope	10.134	-24.154	14.139
Intercept	0.609	1.792	1.314
Tand Slope	11.465	-32.923	23.498
Intercept	1.496	5.151	4.427
	IRI Quadratic		
Sing Slope	2.484	-2.663	-0.734
Intercept	0.250	0.635	0.397
Tand Slope	4.138	-8.899	3.902
Intercept	0.359	1.134	0.887
Trid Slope	5.874	-15.289	9.220

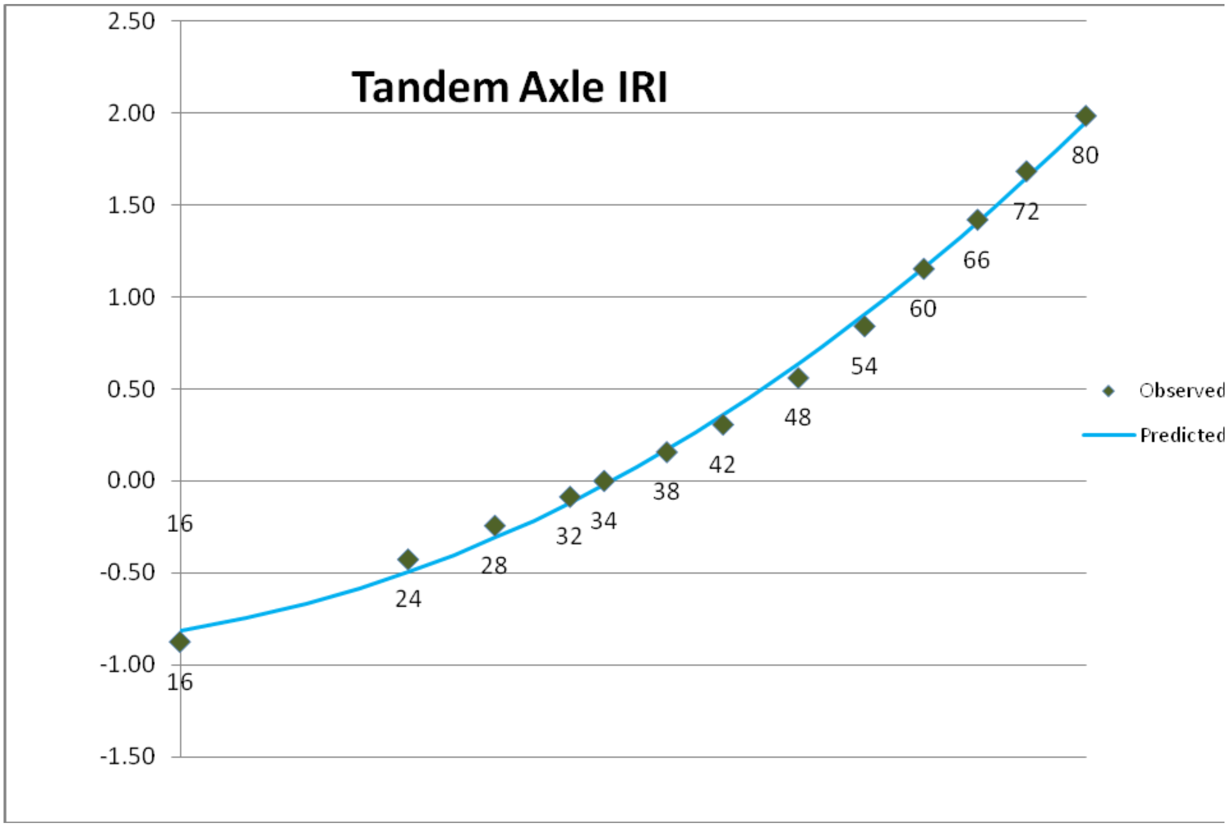
Each of the 17 regressions produced very high correlations between observed and predicted values (the lowest r-square value is 0.9967). See plots of the tandem predicted versus observed Log-LEFs, below.


Tandem Axle Longitudinal Cracking
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
16
24
28
32
34
38
42
48
54
60
66
72
80
Observed
Predicted


Tandem Axle Alligator Cracking
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
16
24
28
32
34
38
42
48
54
60
66
72
80
Observed
Predicted


Tandem Axle AC Rutting
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
-0.2000
-0.4000
-0.6000
-0.8000
16
24
28
32
34
38
42
48
54
60
66
72
80
Observed
Predicted


Tandem Axle Total Rutting
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
16
24
28
32
34
38
42
48
54
60
66
72
80
Observed
Predicted



We repeated the process used for this Rapid City pavement section for 65 rigid and flexible pavement sections while making 7800 runs of the MEPDG model. We developed regression equations for each distress on each pavement section.

Unweighted averages of all the flexible and all the rigid pavement sections produced the LEF estimates contained in Tables A-7 and A-8. For comparison, ESAL values are also included in each table.

Table A-7: National Average Flexible LEFs

Ax Wt Single	ESALs	Long Crk LEFs	Allig Crk LEFs	AC Rut LEFs	Total Rut LEFs	IRI LEFs
3	0.0007	0.0000083	0.00059	0.0118	0.0162	0.0091
4	0.0020	0.000027	0.0019	0.0221	0.0254	0.0137
5	0.0049	0.000066	0.0048	0.0357	0.0373	0.0204
6	0.0101	0.000139	0.0101	0.0530	0.0521	0.0297
7	0.0190	0.00026	0.0190	0.0740	0.0701	0.0423
8	0.0332	0.00045	0.0329	0.0988	0.0915	0.0589
9	0.0544	0.00073	0.0532	0.1275	0.1168	0.0806
10	0.0847	0.00112	0.0820	0.1601	0.1462	0.1083
11	0.1267	0.0016	0.1211	0.1967	0.1801	0.1435
12	0.1829	0.0023	0.1729	0.2374	0.2189	0.1875
13	0.2563	0.0033	0.2399	0.2823	0.2627	0.2421
14	0.3500	0.0044	0.3250	0.3314	0.3122	0.3091
15	0.4673	0.0058	0.4310	0.3847	0.3675	0.3907

16	0.6120	0.0076	0.5614	0.4424	0.4291	0.4893
17	0.7881	0.0097	0.7195	0.5043	0.4974	0.6077
18	1.0000	0.0123	0.9092	0.5707	0.5728	0.7488
19	1.2525	0.0153	1.1345	0.6415	0.6557	0.9162
20	1.5510	0.0188	1.3996	0.7168	0.7465	1.1136
21	1.9013	0.0230	1.7090	0.7965	0.8456	1.3452
22	2.3097	0.0278	2.0675	0.8809	0.9535	1.6157
23	2.7834	0.0333	2.4802	0.9697	1.0795	1.9301
24	3.3298	0.0396	2.9522	1.0632	1.2665	2.2943
25	3.9574	0.0467	3.4892	1.1614	1.4970	2.7143
26	4.6751	0.0549	4.0970	1.2642	1.7806	3.1970
27	5.4924	0.0640	4.7815	1.3717	2.1294	3.7499
28	6.4197	0.0742	5.5491	1.4840	2.5581	4.3810
29	7.4681	0.0856	6.4064	1.6010	3.0850	5.0993
30	8.6494	0.0983	7.3602	1.7228	3.7326	5.9145
31	9.9761	0.1123	8.4176	1.8494	4.5283	6.8369
32	11.4615	0.1278	9.5860	1.9808	5.5063	7.8781
33	13.1197	0.1449	10.8730	2.1171	6.7079	9.0502
34	14.9657	0.1636	12.2865	2.2583	8.1844	10.3668
35	17.0150	0.1841	13.8346	2.4045	9.9981	11.8420
36	19.2843	0.2065	15.5257	2.5555	12.2255	13.4916
37	21.7909	0.2309	17.3687	2.7115	14.9602	15.3322
38	24.5532	0.2574	19.3723	2.8725	18.3164	17.3818
39	27.5901	0.2862	21.5459	3.0385	22.4334	19.6598
40	30.9219	0.3173	23.8990	3.2095	27.4811	22.1870
41	34.5694	0.3509	26.4413	3.3856	33.6665	24.9856

Ax Wt Tandem	**ESALs**	**Long Crk LEFs**	**Allig Crk LEFs**	**AC Rut LEFs**	**Total Rut LEFs**	**IRI LEFs**
6	0.00096	0.00087	0.00086	0.0244	0.0313	0.0756
8	0.0028	0.0028	0.0028	0.0452	0.0504	0.0661
10	0.0067	0.0069	0.0069	0.0728	0.0748	0.0695
12	0.0139	0.0145	0.0145	0.1076	0.1052	0.0799
14	0.0262	0.0271	0.0271	0.1496	0.1421	0.0966
16	0.0456	0.0467	0.0466	0.1992	0.1861	0.1198
18	0.0748	0.0754	0.0753	0.2563	0.2378	0.1508
20	0.1166	0.1157	0.1156	0.3211	0.2976	0.1913
22	0.1743	0.1704	0.1703	0.3938	0.3664	0.2434
24	0.2517	0.2427	0.2426	0.4744	0.4446	0.3099
26	0.3526	0.3361	0.3359	0.5631	0.5329	0.3940
28	0.4814	0.4542	0.4540	0.6599	0.6319	0.4998
30	0.6428	0.6012	0.6011	0.7650	0.7423	0.6321
32	0.8419	0.7816	0.7815	0.8783	0.8648	0.7965
34	1.0841	1.0000	1.0000	1.0000	1.0000	1.0000

36	1.3756	1.2615	1.2617	1.1302	1.1486	1.2505
38	1.7229	1.5716	1.5720	1.2688	1.3113	1.5577
40	2.1335	1.9360	1.9366	1.4161	1.4960	1.9326
42	2.6153	2.3607	2.3616	1.5720	1.8361	2.3883
44	3.1771	2.8521	2.8534	1.7366	2.2777	2.9402
46	3.8286	3.4169	3.4188	1.9100	2.8504	3.6060
48	4.5803	4.0622	4.0649	2.0922	3.5932	4.4063
50	5.4436	4.7954	4.7989	2.2833	4.5571	5.3649
52	6.4307	5.6243	5.6288	2.4833	5.8081	6.5094
54	7.5550	6.5568	6.5625	2.6922	7.4327	7.8715
56	8.8306	7.6014	7.6085	2.9102	9.5430	9.4876
58	10.2727	8.7668	8.7756	3.1372	12.2848	11.3994
60	11.8976	10.0621	10.0729	3.3734	15.8472	13.6546
62	13.7225	11.4967	11.5097	3.6187	20.4752	16.3075
64	15.7658	13.0804	13.0960	3.8732	26.4862	19.4201
66	18.0467	14.8232	14.8418	4.1369	34.2901	23.0628
68	20.5859	16.7357	16.7576	4.4099	44.4167	27.3152
70	23.4048	18.8286	18.8542	4.6922	57.5486	32.2678
72	26.5264	21.1129	21.1428	4.9839	74.5649	38.0225
74	29.9743	23.6003	23.6349	5.2850	96.5959	44.6945
76	33.7739	26.3024	26.3423	5.5955	125.0929	52.4132
78	37.9514	29.2315	29.2773	5.9154	161.9165	61.3245
80	42.5343	32.4001	32.4524	6.2449	209.4485	71.5918
82	47.5516	35.8209	35.8804	6.5839	270.7337	83.3983

Ax Wt Tridem	**ESALs**	**Long Crk LEFs**	**Allig Crk LEFs**	**AC Rut LEFs**	**Total Rut LEFs**	**IRI LEFs**
12	0.0034	0.0095	0.0031	0.0639	0.9643	0.1397
15	0.0080	0.0235	0.0076	0.1032	0.4820	0.1175
18	0.0167	0.0494	0.0159	0.1528	0.3416	0.1184
21	0.0315	0.0926	0.0299	0.2128	0.2985	0.1323
24	0.0550	0.1597	0.0515	0.2835	0.2981	0.1574
27	0.0901	0.2581	0.0833	0.3652	0.3254	0.1948
30	0.1405	0.3967	0.1281	0.4580	0.3779	0.2471
33	0.2101	0.5851	0.1889	0.5621	0.4581	0.3186
36	0.3033	0.8343	0.2694	0.6777	0.5729	0.4148
39	0.4249	1.1564	0.3734	0.8049	0.7326	0.5433
42	0.5801	1.5644	0.5051	0.9439	0.9521	0.7137
45	0.7746	2.0726	0.6692	1.0948	1.2518	0.9387
48	1.0145	2.6966	0.8707	1.2577	1.6595	1.2342
51	1.3064	3.4529	1.1150	1.4328	2.2126	1.6207
54	1.6576	4.3592	1.4077	1.6201	2.9614	2.1239
57	2.0762	5.4345	1.7549	1.8197	3.9727	2.7766
60	2.5709	6.6989	2.1633	2.0318	5.3357	3.6195

63	3.1515	8.1735	2.6395	2.2565	7.1685	4.7039
66	3.8286	9.8808	3.1909	2.4937	9.6271	6.0934
69	4.6137	11.8445	3.8252	2.7438	12.9166	7.8669
72	5.5195	14.0893	4.5502	3.0066	17.3064	10.1223
75	6.5598	16.6412	5.3745	3.2823	23.1487	12.9798
78	7.7493	19.5274	6.3067	3.5710	30.9024	16.5872
81	9.1041	22.7762	7.3561	3.8727	41.1641	21.1255
84	10.6412	26.4173	8.5321	4.1876	54.7061	26.8154
87	12.3790	30.4814	9.8449	4.5157	72.5263	33.9255
90	14.3371	35.0004	11.3046	4.8570	95.9089	42.7815
93	16.5362	40.0077	12.9221	5.2116	126.5028	53.7774
96	18.9984	45.5376	14.7084	5.5797	166.4181	67.3887
99	21.7471	51.6258	16.6750	5.9612	218.3483	84.1873
102	24.8068	58.3090	18.8339	6.3563	285.7210	104.8593

Appendix B: HERS / NAPCOM Distress Models

These models and this description are the work of a joint venture of Applied Research Associates (ARA) and Battelle. These models are still under evaluation and may be adjusted or modified before their final adoption.

PCC Pavement (JPCP) Models

Transverse "Slab" Cracking Model

$$\text{CRACK} = \left(\frac{100}{1 + 733085^{-0.00521*(\text{ESALS*LB\_TRF\_FACTOR})^{0.25} + ?}} \right) \quad (1)$$

Where

CRACK = percent slabs cracked

ESALs = cumulative number of 18-kip equivalent single axle load

$$\text{LB\_TRAF\_FACTOR} = \left(\frac{1}{1 + \left[\frac{\text{AGE}}{\text{LB\_AGE} + 5.41} + 0.0000001 \right]^{-7.89}} \right) \quad (2)$$

AGE = pavement age in years

LB_AGE = age at which the PCC slab debonds from the base. LB_AGE depends on the underlying base material type. For ATB, LB_AGE = 26.7 years, for CTB, it is 18.8 years, while for granular bases, LB_AGE = 15.0 years

$$\begin{aligned} \text{LN}(\Delta) = {} & \gamma_1 *(\text{EdgeSup}) + \gamma_2 *\text{EPCC} + \gamma_3 *\text{JTSP} + \gamma_4 *\text{PCC\_COMP} \\ & + \gamma_5 *\text{PCCTHK} + \gamma_6 *\text{SUBGCOAR} + \gamma_7 *\text{CLIMWF} \\ & + \gamma_8 *\text{CLIMWNF} + \gamma_9 *\text{CLIMDNF} \end{aligned} \quad (3)$$

A description of the coefficient and input variables used for computing the natural log of Δ is presented below:

Coefficient	Estimate	Description of Variables
γ_1	0.1424	EdgeSup (Edge support), 1 if a tied PCC shoulder or widened slab (slab width > 12 ft) is used, otherwise 0
γ_2	- 3.36E-7	EPCC = 28-day PCC slab elastic modulus in psi. It is computed from the PCC compressive strength as follows: $E_{PCC} = 57000\sqrt{f_C^{'}}$, where $f_C^{'}$ = 28-day PCC compressive strength in psi
γ_3	- 0.0571	JTSP = JPCP joint spacing or slab length in feet
γ_4	0.000188	PCC_COMP = 28-day PCC compressive strength in psi
γ_5	0.0598	PCCTHK = PCC slab thickness in inches
γ_6	0.2951	SUBGCOAR = 1 if subgrade material is coarse grained, otherwise 0
γ_7	0.1323	CLIMWF = 1 if pavement is located in a wet-freeze climate (i.e., annual rainfall is > 20 in and freezing index (FI) > 150 deg F days), otherwise 0
γ_8	0.2443	CLIMWNF = 1 if pavement is located in a wet-no-freeze climate (i.e., annual rainfall is > 20 in and freezing index (FI) < 150 deg F days)), otherwise 0
γ_9	0.7636	CLIMDNF = 1 if pavement is located in a dry-no-freeze climate (i.e., annual rainfall is < 20 in and freezing index (FI) < 150 deg F days)), otherwise 0

NOTE: DESCRIPTIONS OF CLIMATE ZONES ARE PROVIDED BY LTPP. NOTE THAT COARSE-GRAINED SOILS ARE DESCRIBED BY AASHTO SOIL CLASSIFICATIONS A-1-a THROUGH A-3 WHILE FINE-GRAINED SOILS ARE DESCRIBED BY AASHTO SOIL CLASSIFICATIONS A-4 THROUGH A-7-6.

Transverse Joint Faulting Model

$$\begin{aligned} PFAULT = {} & (ESALS^{0.521})*(1 - 0.6413*DowDia)*(-9.01E-06*ATB \\ & -9.50E-06*CTB + 0.000013*EdgeNone + 1.44E-08*FI \\ & + 3.68E-06*JTSP + 0.000014*WET -4.91E-06*PCCTHK \\ & -9.36E-06*SubgCoar) \end{aligned} \quad (4)$$

Where

PFAULT = mean transverse joint faulting, in.

ESALs = cumulative number of 18-kip equivalent single axle load

DowDia = dowel diameter, in.

ATB = 1 if base type is asphalt treated material, otherwise 0, for ATB = 1, base modulus (BaseMod) = 200,000 psi

CTB = 1 if base type is cement treated material, otherwise 0, for CTB = 1, base modulus (BaseMod) = 1,000,000 psi

EdgeNone = 1 if no edge support is provided at the pavement slab edge, otherwise 0

FI	=	freezing index, deg F days
JTSP	=	JPCP joint spacing or slab length, ft.
WET	=	1 if climate is "Wet-Freeze" or "Wet-Nofreeze" as defined by LTPP, otherwise 0
PCCTHK	=	PCC slab thickness in inches
SubgCoar	=	1 if subgrade material is coarse grained, otherwise 0

NOTE THAT COARSE-GRAINED SOILS ARE DESCRIBED BY AASHTO SOIL CLASSIFICATIONS A-1-a THROUGH A-3 WHILE FINE-GRAINED SOILS ARE DESCRIBED BY AASHTO SOIL CLASSIFICATIONS A-4 THROUGH A-7-6.

Transverse Joint Spalling

$$SPALL = \left[\frac{AGE}{AGE + 0.01}\right]\left[\frac{100}{1 + 1.005^{(-12*AGE + SCF)}}\right] \tag{5}$$

Where

SPALL	=	percentage joints spalled (medium- and high-severities)
AGE	=	pavement age since construction, years
SCF	=	scaling factor based on site-, design-, and climate-related variables:

$$SCF = -1400 + 350 * AIR\% * (0.5 + PREFORM) + 43.4\ f'c \wedge 0.4 - 0.2\ (FTCYC * AGE) + 43\ hPCC - 536\ WC\_Ratio \tag{6}$$

SCF	=	spalling prediction scaling factor used in Equation 6
AIR%	=	PCC air content, percent (typically ranging from 4 to 8 percent)
AGE	=	time since construction, years
PREFORM	=	1 if preformed sealant is present; 0 if not
f'c	=	PCC 28-day compressive strength, psi
FTCYC	=	average annual number of air freeze-thaw cycles
hPCC	=	PCC slab thickness, in
WC_Ratio	=	PCC water/cement ratio (by weight)

Flexible Pavement (New HMA & HMA Overlaid HMA) Models

Estimating asphalt layer dynamic modulus (using the Witzak dynamic modulus equation)

$$\log E^* = -1.249937 + 0.02932\rho_{200} - 0.001767(\rho_{200})^2 - 0.002841\rho_4 - 0.058097V_a$$
$$- 0.802208\left(\frac{V_{beff}}{V_{beff} + V_a}\right) + \frac{3.871977 - 0.0021\rho_4 + 0.003958\rho_{38} - 0.000017(\rho_{38})^2 + 0.005470\rho_{34}}{1 + e^{(-0.603313 - 0.313351\log(f) - 0.393532\log(\eta))}} \quad (1)$$

Where

E^*	=	HMA dynamic modulus, psi
η	=	HMA bitumen viscosity, 10^6 Poise
f	=	loading frequency, Hz
V_a	=	as-constructed HMA mix air void content, percent
V_{beff}	=	effective as-constructed HMA mix bitumen content, percent by volume
ρ_{34}	=	cumulative percent retained on the ¾ in sieve for the HMA mix
ρ_{38}	=	cumulative percent retained on the 3/8 in sieve for the HMA mix
ρ_{4}	=	cumulative percent retained on the No. 4 sieve for the HMA mix
ρ_{200}	=	percent passing the No. 200 sieve for the HMA mix

Equation 1 requires several inputs that are available as defaults in the M-EPDG. A full description of these inputs along with equations used to model estimate these inputs are described in NCHRP Projects 1-37A and 1-40D final project reports (ARA 2004; NCHRP 2006).

Model Input Variables/Clusters	Model Coefficients			
	Equation 2	Equation 3	Equation 4	Equation 5
	Horizontal Tensile Strain at the Bottom of HMA Layer	Vertical Strain at the Middle of HMA Layer	Vertical Strain at the Middle of Base Layer	Vertical Strain at the Top of Subgrade Layer
Intercept	0.007706079	-0.010539965	-0.013753501	-0.005714644
ACThk	-0.000875072	0.000580293	0.001795503	0.000670647
ACMod	-0.000371346	0.001475217	0.000590472	0.000206993
BaseThk	-0.000160482	-8.95177E-05	0.000696071	0.000481929
BaseMod	-0.000541586	-3.38384E-05	0.001059805	3.15126E-05
SubgrMod	-5.93918E-05	-8.15273E-05	-3.35863E-05	0.000518046
ACThk*ACThk	0.00001224	3.81811E-05	-4.18585E-05	-9.8384E-06
ACThk*ACMod	1.64491E-05	-5.76145E-05	-0.000026373	-5.7542E-06
ACMod*ACMod	8.595E-07	-5.06666E-05	-2.9108E-06	-1.0728E-06
ACThk*BaseThk	8.3575E-06	7.7843E-06	-6.06075E-05	-4.32508E-05
ACMod*BaseThk	2.5259E-06	6.1704E-06	-2.25257E-05	-1.30924E-05
BaseThk*BaseThk	6.1914E-06	-7.451E-07	1.6373E-06	-1.4025E-06
ACThk*BaseMod	4.17036E-05	2.4867E-06	-8.40397E-05	-6.8449E-06
ACMod*BaseMod	2.34109E-05	3.4547E-06	-3.06634E-05	-1.8974E-06
BaseThk*BaseMod	1.5431E-06	-2.6824E-06	-1.68535E-05	3.5859E-06
BaseMod*BaseMod	2.8965E-06	-5.528E-07	-1.74637E-05	1.4018E-06
ACThk*SubgrMod	1.1711E-06	0.000005491	7.128E-07	-3.41892E-05
ACMod*SubgrMod	-3.461E-07	4.4916E-06	5.702E-07	-1.04126E-05
BaseThk*SubgrMod	5.5404E-06	0.000002114	-1.8562E-06	-2.26448E-05
BaseMod*SubgrMod	3.2144E-06	-1.213E-07	5.3833E-06	-3.1661E-06
SubgrMod*SubgrMod	3.526E-07	9.21E-08	-2.1207E-06	-0.000009591

NOTES:

- ACThk = total HMA layer thickness, in
- ACMod = HMA dynamic modulus, psi
- BaseThk = base layer thickness
- BaseMod = base layer modulus, psi
- SubgrMod = subgrade layer modulus
- For Equation 2, if the estimated tensile strain is less than 0, set tensile strain to 0.000001.
- For Equations 3, 4 and 5, if the vertical compressive strain is greater than 0, set vertical compressive strain to 0.000001, otherwise vertical compressive strain = estimated value * -1.

Alligator cracking (new flexible and asphalt overlaid flexible pavement)

$$ACRK = \frac{89.644}{0.1331 + 7.6199 \sum_{n=1}^{n=k} FDAM^{-0.8361}} \quad (6)$$

Where

ACRK = alligator cracking, percent area

FDAM = $\frac{MESAL}{N_f}$

MESAL = total 18-kip ESALs for a given month

k = total number of months in analysis period

N_f = $1.2347 * 0.00432 * k_1 * C * \left(\frac{1}{E}\right)^{1.281*\beta_1} * \left(\frac{1}{\varepsilon_t}\right)^{3.9492*\beta_2}$

k_1 = $\frac{1}{0.000398 + \frac{0.003602}{1 + e^{(11.02 - 3.49 \times h_{AC})}}}$

C = 10^M

M = $4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$

β_1 = 1.2

β_2 = 1.0672

E* = HMA layer dynamic modulus (at the bottom of the HMA layer), psi

ε_t = tensile strain at the bottom of the HMA layer (computed using Equation 2)

h_{AC} = HMA layer thickness, in.

V_a = HMA mix as-constructed air voids, percent

V_b = HMA mix effective as-constructed placed volumetric binder content, percent

Rutting (new flexible and asphalt overlaid flexible pavement)

$$TRUT = ACRUT + BASERUT + SUBGRUT \quad (7)$$

Where

TRUT = total pavement rutting

ACRUT	=	rutting in the HMA layer, in.
BASERUT	=	rutting in the base layer, in.
SUBGRUT	=	rutting in the subgrade layer, in.

HMA Layer Rutting

$$ACRUT = 0.000493 \times MAAT^{1.5606} \times \sum_{n=1}^{k} \left(\varepsilon_{vHMA} \times MESAL^{0.4791} \right) \quad (8)$$

Where

ε_{vHMA}	=	vertical strain in the asphalt layer (3 in. below the surface, computed using Equation 3)
MAAT	=	mean annual air temperature, °F
MESAL	=	total 18-kip ESALs for a given month
k	=	total number of months in analysis period

Base Rutting

$$BASERUT = 4.4833 * \varepsilon_{vBASE} * h_B * CESAL^{0.1307} \quad (9)$$

where

ε_{vBASE}	=	vertical strain in the middle of the BASE layer (computed using Equation 4) USE REPRESENTATIVE ε_{vBASE} FOR THE ENTIRE ANALYSIS PERIOD
h_B	=	base layer thickness, in.
CESAL	=	cumulative 18-kip ESALs over the entire analysis period

Subgrade Rutting

$$SUBGRUT = (0.0025 PRECIP + 0.000080 FI) \left(\frac{\varepsilon_o}{\varepsilon_r} \right)^{0.9692} e^{-\left(\frac{\rho}{CESAL} \right)^{\beta}} \left(\varepsilon_{vSUBG} \right)^{0.1116} \quad (10)$$

Where

ε_{vSUBG}	=	vertical strain in the top 12 in. of the subgrade (computed using Equation 5) USE REPRESENTATIVE ε_{vSUBG} FOR THE ENTIRE ANALYSIS PERIOD
PRECIP	=	mean annual precipitation/rainfall, in.
FI	=	mean annual freezing index, °F days
CESAL	=	cumulative 18-kip ESALs over the entire analysis period
β	=	$0.7 * 10^{(-0.61119 - 0.017638 Wc)}$
ρ	=	$10^{(0.622685 + 0.541524 Wc)}$
$\left(\frac{\varepsilon_o}{\varepsilon_r} \right)$	=	$10^{(0.74168 + 0.08109 Wc - 0.000012157 * E_{SUBG})}$

$W_c \quad = \quad 51.712 * CBR_{SUBG}^{-0.3586 \times GWT^{0.1192}}$

GWT = depth to ground water table (typical range is 5 to 40 ft)

$CBR_{SUBG} = \left(\frac{M_r}{2555}\right)^{1.5625}$

Mr = subgrade resilient modulus at optimum moisture content, psi

E_{SUBG} = Mr

Transverse cracking (new flexible and asphalt overlaid flexible pavement)

$$TCRK = \frac{3.581}{0.0417 + \left(\frac{AGE}{FACTOR}\right)^{-1.8898}} \tag{11}$$

$$TCRK = 10 \times \left(\frac{AGE}{AGE + 0.01}\right) \times \frac{5.3581}{0.0417 + FACTOR^{-1.8898}}$$

AGE = pavement age in years

FACTOR = 62.5 + 14.9986*S_HMATHK – 40.9967*loglogη – 6.9433*AVOID

+ 0.4584*PCT¾ – 3.3029*FTCYC

Where

TCRK = number of transverse cracks per mile

S_HMATHK = asphalt (surface) layer thickness (TYPICALLY 0.15 to 0.30 of the total HMA layer thickness)

loglogη = log log of HMA mix initial as-constructed viscosity (use same values as that in the Witzak model)

AVOID = HMA mix initial as-constructed air voids

PCT3/4 = percent passing ¾ in. sieve for HMA mix

FTCYC = mean annual air freeze-thaw cycles

Smoothness (IRI) (new flexible and asphalt overlaid flexible pavement)

IRI = INI_IRI + 40.0*MRUT + 0.4*CRACK + 0.008*TRANS_CK

+ 0.015*SF (12)

Where

INI_IRI = initial IRI, in/mi

MRUT	=	mean rut depth, in.
CRACK	=	alligator cracking, percent area
TRANS_CK	=	transverse cracking, ft/mile
SF	=	FROSTH + SWELLP*AGE$^{1.5}$
FROSTH	=	LN([PRECIP+1]*FINES*[FI+1])
SWELLP	=	LN([PRECIP+1]*CLAY*[PI+1])
FINES	=	FSAND + SILT
AGE	=	pavement age, years
PI	=	subgrade soil plasticity index
PRECIP	=	mean annual precipitation, in.
FI	=	mean annual freezing index, deg. F Days
FSAND	=	amount of fine sand particles in subgrade (percent of particles between 0.074 and 0.42 mm)
SILT	=	amount of silt particles in subgrade (percent of particles between 0.074 and 0.002 mm)
CLAY	=	amount of clay size particles in subgrade (percent of particles less than 0.002 mm)

Default fine and coarse subgrade soil properties are presented below:

Subgrade Properties	Fine Soils	Coarse Soils
Resilient modulus, psi	14,200	22,857
Amount of fine sand particles in subgrade (percent of particles between 0.074 and 0.42 mm) (FSAND), percent	11	13
SILT (amount of silt particles in subgrade, percent of particles between 0.074 and 0.002 mm), percent	33	14
CLAY (amount of clay size particles in subgrade (percent of particles less than 0.002 mm), percent	24	6
Plasticity index, percent	16	8

Reflection cracking (asphalt overlaid JPCP)

$$RCRK = \frac{100}{1 + 2.718^{a(c)+b(AGE)(d)}} \tag{13}$$

Where

RCRK	=	percent of cracks reflected, percent area of reflection cracking assumes a reflected crack width of 1ft.
AGE	=	pavement age (years after asphalt overlay placement)

The values of the reflective cracking model parameters a, b, c, and d are presented below:

Pavement Type	Effective Asphalt Overlay Thickness	Model Parameters				
		a	b	c	d	
					Delay Cracking by 2 yrs	Accelerate Cracking by 2 yrs
Rigid with good load transfer ($H_{eff} = H_{HMA} – 1$)	< 4	$a = 3.5+0.75*H_{eff}$	$b = -0.688 – 3.373*(H_{eff})^{-0.9154}$	1.0	0.6	3.0
	4 to 6			1.0	0.7	1.7
	> 6			1.0	0.8	1.4
Rigid with poor load transfer ($H_{eff} = H_{HMA} – 3$)	< 4			1.0	0.6	3.0
	4 to 6			1.0	0.7	1.7
	> 6			1.0	0.8	1.4

H_{HMA} = asphalt overlay thickness, in.

Smoothness (IRI) (composite pavement [asphalt overlaid JPCP and JRCP])

The IRI prediction model adopted from the M-EPDG is as follows:

$$IRI = INI\_IRI + 40.8*MRUT + 0.575*CRACK + 0.0014*TRANS\_CK + 0.00825*SF \quad (14)$$

All variables are as already defined.

NOTE THAT TRANS_CK MUST INCLUDE ALL REFLECTION CRACKING (TRANSVERSE JOINTS AND TRANSVERSE CRACKS) FROM THE EXISTING JOINTED CONCRETE PAVEMENT.

Issue Paper 7:

Treatment of "Unallocable" Costs

Mark Ford, Mark Ford and Associates, LLC

1.0 Introduction and Summary

The purpose of this paper is to consider the allocation of expenditures that are not affected by vehicle use and do not add capacity. These have been termed "unallocable" costs. They include the following:

- Roadside improvements and maintenance
- Bicycle and pedestrian projects
- Railroad safety projects (mainly at-grade crossings)
- Fish- and wildlife-enabling projects
- Transportation demand management
- Planning
- Administration

Currently these costs are assigned on a per mile basis ('All VMT' allocator) or in proportion to passenger car-equivalent vehicle-miles traveled during the peak hour ('Congested PCE' allocator), which varies in proportion to each vehicle's contribution to congestion on existing facilities, but does not take into account the relationship between volume and capacity on existing facilities. The question to be addressed in this paper is whether there are other assignment techniques that would be more consistent with Oregon's cost allocation philosophy.

Section 2.0 reviews fundamental pricing principles and their implications for allocation of these costs in a perfect world in which highways are priced according to marginal costs. The paper concludes that this is the most economically efficient approach and one that should be considered as the state moves toward efficient fee and congestion pricing, but that this approach is not feasible at the present time.

Section 3.0 reviews principles of cost allocation and establishes tests for whether expenditures are truly unallocable and how they should be allocated in theory. Section 4.0 reviews five potential allocators for unallocable costs available in our current highway cost allocation framework, including VMT and Congested PCE allocators. Section 5.0 then reviews each of the seven categories of costs listed above and identifies alternative allocators that meet the criteria developed in Section 3.0. This last section ends by demonstrating how choices of different allocators would affect the distribution of costs between light and heavy vehicles.

1.1 Summary of Findings

The cost categories identified above as "unallocable" account for approximately 32 percent of costs allocated in the 2009 study. Within the constraints of Oregon's cost responsibility philosophy there is no definitive economic rationale for any particular treatment of these unallocable costs. In some cases road users do not receive direct benefit from these expenditures. In other cases, they receive benefit, but no particular class of vehicles bears direct responsibility of the cost of these expenditures. In cases in which users benefit, VMT or PCE often bear some relationship to the level of benefit received and are therefore equitable, if not perfectly efficient, allocators. In a few cases, discussed in the body of the paper, other approaches may be justified.

Table 1 summarizes the conclusions for each of the cost categories evaluated. The alternatives identified in the table are not recommendations.

- Roadside improvements and maintenance benefit road users generally and no alternative to the current practice of allocating these expenditures by VMT was identified.

- Bicycle and pedestrian costs are currently allocated on the basis of congested PCE, which is logical if the primary benefit is seen as reduction of traffic demand and improvement of traffic flow. These costs could also be allocated to light vehicles on a per mile or per vehicle basis on the theory that they provide alternatives to passenger travel that potentially benefit individual passenger trips.
- Railroad safety projects are currently allocated by VMT because they benefit all road users in proportion to use of the system. This analysis suggests that because some of the cost of rail safety projects involve resurfacing crossings, there is an incremental component associated with axle weights as well.
- Demand management projects could be either allocated on congested PCE based on the benefits in reducing capacity needs or allocated to light vehicles based on the fact that many of these projects are intended to provide options for travelers using light vehicles.
- Planning costs could logically be allocated on a per vehicle basis to all vehicles or on a VMT basis.
- Administrative costs are such a large portion of total allocated costs that their treatment has a significant impact on study results. Currently these costs are allocated on the basis of VMT. It is recommended that future studies subdivide these costs and consider whether VMT is the logical allocator. Some of these costs could logically be treated as overhead and allocated according to all other costs because they are general costs of delivering the entire program.

This paper ends with an evaluation of the potential impact on cost allocation of implementing some of the alternatives considered. The evaluation finds that, depending on how administrative costs are treated, alternative methods of distributing unallocable costs could result in as much as a 6 percent shift from light to heavy vehicles. This finding further reinforces the need to subdivide and carefully consider how administrative costs are allocated in future studies.

Table 1. Summary of Treatment of Unallocable Costs

Cost Category	Current Allocator	Alternatives for Consideration
Roadside improvements and maintenance	VMT	VMT
Bicycle and pedestrian projects	Congested PCE	Congested PCE, VMT, light vehicle VMT, or per passenger vehicle
Railroad safety projects	VMT	VMT and roadway cost increments
Fish- and wildlife-enabling projects	VMT	VMT
Demand management	Congested PCE	Congested PCE, light vehicle VMT, or per light vehicle
Highway planning	VMT	VMT or per vehicle
Administration	VMT	As overhead, proportionate to all other allocations with certain components by VMT or per vehicle

2.0 Unallocable Costs Under Marginal Cost (Efficient Fee) Pricing

2.1 A Marginal Cost Pricing and Unallocable Costs

Economists have spent considerable time and engaged in much debate about the pricing of publicly provided services. There has been general consensus that when goods and services are not produced in a competitive market they should be priced according to marginal costs.1 According to this principle each new user of the system pays the additional costs of their use. Oregon's incremental approach to cost responsibility contains elements of this approach in that each vehicle is expected to pay the additional costs to public agencies of providing these services. However, in practice, it is likely that the methods used to collect optimal user fees would result in average rather than marginal cost pricing.

In a world with marginal cost pricing of roads, the revenue collected from the efficiently determined optimal pricing should be enough to cover both the variable and fixed costs for the system. Most studies of the long-run cost function conclude that highways exhibit constant returns or declining returns to roadway scale. If highways exhibit constant returns to scale, then short-run optimal pricing yields sufficient revenue to finance expansion in capacity, including those costs that are fixed (and, thus, seemingly unallocable) in the short-run. If highways display decreasing returns to scale (because of right of way constraints, the tendency to experience higher site acquisition and construction costs due to regional growth and the need to incur expenses to mitigate construction-related delay, etc.), then the levy of optimal short-run tolls will generate funds in excess of those needed to build out the system.

In either case, therefore, there would be no need to "allocate the unallocable costs". Rather, the levy of marginal cost charges would be sufficient to cover all capital costs over time. Thus, to the extent that the quality of service desired from the roadway system involves capital spending for the protection of fish, accommodation of bicycles, etc., the long-run average and marginal costs are elevated. This means that one still follows the short-run marginal pricing rule, but new investment will be triggered only at a somewhat higher short-run toll level and delayed somewhat in time. There would be no "unallocable cost" issue as long as long-run marginal costs of capacity are inclusive of these costs that are fixed in the short run.

The problem for regulated utilities or public agencies operating under economies of scale (increasing returns) is how to recover all of their costs if they wish to charge only marginal costs to their customers. The most economically efficient solution is to allocate costs to different categories of users in proportion to the inverse elasticity of demand (also called Ramsey pricing).2 In other words, charge more to those user groups who will be the last to give up the service as prices rise and less to those who would leave at lower prices. In this way, users cover their variable costs and make a contribution toward common costs, and the maximum number of users, consistent with capacity, enjoy the benefits of the services and facilities.

This type of pricing is observed in electric utilities, which often provide interruptible power at reduced rates and charge premium rates at periods of high demand. Highways with variable tolls price their facilities so that users pay at least their individual variable cost, at which point highways increase rates as the facility becomes more crowed. Those with a more elastic demand for services are more quickly priced off the facility while higher prices are paid by those who place greater value on using the facility.

Ramsey pricing of common costs would for highway cost allocation purposes would be undesirable given there is larger variation of elasticity of demand within vehicle classes, not necessarily neatly across vehicle classes. Additionally, if it is true that there are not economies of scale in road building, however, Ramsey pricing is unnecessary.

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[1] Howe, K. M. and E. F. Rasmussen (1982). *Public Utility Economics and Finance*, p. 19.

[2] Baumol, W. J. and D. F. Bradford (1970). Optimal Departures from Marginal Cost Pricing. *American Economic Review, 60*(3), 265-283.

2.2 Common Costs Approach

The remaining fixed costs, which are not directly attributable to a specific class of user and do not vary with use, are referred to as "common costs." These fixed or common costs are similar to the unallocable costs of the highway cost allocation process. In fact, some state cost allocation studies refer to non-weight, non-wear related costs as common costs.3

There would be several benefits to allocating common costs based on inverse elasticity of demand. First, the road system would be better utilized and service would be improved. This approach would result in costs for users at times and places where they are not creating congestion. On the other hand, users with inelastic demand would make a larger contribution to common costs.

If the common costs associated with the provision of highway infrastructure could be charged to users on a demand-related basis, this would create some of the flexibility in road pricing needed to implement efficient fee and marginal cost pricing. Agencies would still operate with a balanced budget and payments by users could still be dedicated to roads. As noted, the costs directly analyzed in this paper accounted for 32 percent of total allocated costs. Including other common costs, such as basic increments of construction that are not affected by size or amount of travel, could bring total common costs to more than 50 percent of all allocated costs. This alternative treatment of common costs would allow "demand sensitive" components of a variable fee structure to have a very wide range while still keeping total revenue collections equal to total expenditures.

Because most costs allocated to light vehicles in current cost allocation procedures are common costs, there is a large potential to vary fees within this class. For heavy vehicles there is less potential variability because they already have higher fees due to damage-related costs and incremental construction costs and because the relative amount of common costs built into their current fees is smaller.

2.2 Current Limits on Marginal Cost Pricing Solutions

Currently, allocation of common costs by demand for services is not feasible. First, current fees are calibrated based on vehicle weight. But weight is only one component in determining demand for road infrastructure. Other important considerations are trip purpose, time of day, location, available alternatives, and flexibility.

Second, the technology is not yet in place to collect fees on a basis that would be closely related to demand for services. When it becomes feasible to charge by time of day, location, or trip purpose, such a fee system would be very feasible.

In spite of these limitations, the option of charging common or unallocable costs on a demand basis should be kept on the table for future consideration, especially in evaluating the potential implementation of efficient fees. This approach would make the road financing process more economically efficient and would help to implement efficient fee and congestion pricing.

3.0 Clarification of "Unallocability"

Oregon's fundamental approach to cost responsibility is that road users should make payments in proportion to the provision costs of the roads they use. Oregon uses a cost-occasioned approach that considers incremental costs of providing facilities to serve progressively larger vehicles as well as costs of maintenance and repair due to vehicle use. However, many expenditures, like those identified in this paper, do not vary with use or weight. Consequently, there is no basis within the cost occasion framework to allocate these costs. The general practice has been to allocate such expenditures by

[3] Both Arizona and Texas take this approach. *NCHRP, State Highway Cost Allocation Studies*, 2008, p 11.

VMT or PCE on the basis that these measures bear a relation to the benefits received and are therefore equitable.

Some of the unallocable costs considered in this paper, such as fish and wildlife passage, are mitigation requirements to reduce negative environmental impacts of roads. These costs are associated with the road network and would not be necessary if roads did not exist. Because the logical alternative would be to eliminate the road, users are generally beneficiaries. Therefore, in cases where amount of use or vehicle size and weight affects the costs of mitigation, these costs should be allocated accordingly. When mitigation measures are associated with construction of a facility, they will logically become part of the construction cost and allocated as such. However, mitigation measures are retrofits to existing roadways, and the identification of incremental costs should consider whether the actual presence of larger and heavier vehicles affects cost, considering that the original roadway is already in place and would require the same modification even if only light vehicles were using it.

Based on these considerations, the following factors were considered in evaluating and allocating unallocable costs:

- Does the expenditure benefit users or particular classes of users? If so, the allocating mechanism should reflect these benefits.
- Within the classes of benefiting vehicles are there incremental costs associated with size and weight? If so, the allocating mechanism should reflect these incremental costs.
- If there are no cost increments associated with the benefiting classes of vehicles, then the allocating mechanism should be based on generally accepted measures of equity.
- Whether or not road users benefit from the expenditures, do different classes and weights of vehicles create incrementally higher costs in these expenditure categories? If so, because these costs are part of the road program, the allocation should reflect the incremental costs.

4.0 Alternatives for Distributing Unallocable Costs

There are a number of alternative approaches that could be used to assign unallocable costs for highway cost allocation purposes:

4.1 Allocation by Vehicle Miles of Travel

This is the method most commonly used in the Oregon HCAS. When benefits of an expenditure category are proportionate to amount of use, but not related to vehicle size or weight, this allocator is an appropriate allocator. In other cases it appeals to equity in that all users contribute to covering expenditures and do so in proportion to use.

In the case of motor carrier costs, VMT is used to allocate common costs among subclasses of heavy vehicles.

4.2 Allocation by Passenger Car Equivalent

Some of the costs “unallocable” costs analyzed here use congested-PCE as an allocator. This measure may be logical for expenditures that reduce congestion for two reasons. First, because congested PCE is a measure of how the need for the expenditure was created; and second, because it bears some relationship to the benefits received by users. Because trucks have higher PCEs than passenger cars, a shift from VMT to PCE would shift costs from light to heavy vehicles.

4.3 Allocation Per Vehicle

An alternative to allocating by VMT would be to allocate on a per vehicle basis. Because truly unallocable costs are not related to amount of use it may be appropriate to treat them as fixed costs and charge them on a per vehicle basis as an entry fee to the system. Because light vehicles travel fewer miles per vehicle, this approach would shift costs to light vehicles.

4.4 Allocation as Overhead

Allocating common costs in proportion to all other costs connects with the overall-cost-responsibility philosophy by maintaining a proportional relationship to the cost of providing the system from which the user benefits. Because heavier vehicles have higher per mile and per vehicle responsibility for direct costs, this method would shift more responsibility to heavy vehicles.

4.5 Allocation by Inverse Elasticity of Demand

As discussed in Section 2.0 the most economically efficient allocation of common costs is by inverse elasticity of demand. At the present time it is not feasible to calculate the appropriate distribution nor to collect fees on this basis. See Section 2.0 for more detail.

5.0 Review of Current Unallocable Costs

For each category of unallocable costs, this section first discusses the tests described in Section 2.0 and then considers whether alternative allocation methods would be consistent with Oregon's cost responsibility philosophy.

5.1 Roadside Improvements and Maintenance

These costs include signing, lighting, landscaping, drainage, and other expenditures not directly on the road. These are common costs that do not add capacity and are not affected by the volume of use. They constitute 4.8 percent of total costs allocated in the 2009 study. These are common costs that generally benefit all road users in proportion to the amount of use.

In some cases there may be incremental costs associated with roadside improvements. For instance, the Federal Highway Administration found in its 1997 cost allocation study that trucks have higher responsibility for noise barriers.[4] However, any incremental components are likely to be minor compared to the overall cost category. If significant incremental costs are found, they could be analyzed separately in future studies.

Currently these costs are allocated by VMT. Because these benefits are enjoyed by road users roughly in proportion to their use of the system, this is a better reflection of benefits received than other potential measures.

5.2 Bicycle and Pedestrian Projects

Bicycle and pedestrian projects constitute 2.0 percent of expenditures allocated in the 2009 study. There are three general arguments as to why bicycle and pedestrian projects may benefit road users. First, separation of pedestrians and bicyclists increases safety. Second, separation may improve motor vehicle flow. And third, such projects provide a travel alternative for certain passenger trips.

There do not appear to be incremental costs associated with vehicle size and weight that would affect the cost of bicycle or pedestrian facilities. To the extent that these measures reduce congestion in urban areas, congested PCE would bear some relationship to the creation of these costs.

To the extent that improved traffic flow and safety are reasons for developing bicycle paths and sidewalks, VMT is probably the best measure of benefits to road users. To the extent that these facilities are provided as an alternative for passenger travel, it may be appropriate to charge these costs to light vehicles, possibly on a per vehicle basis.

In summary, if bicycle and pedestrian facilities are viewed as safety measures or traffic improvement measures, then allocation on the basis of congested PCE is appropriate. If they are viewed as an alternative to auto travel, then charging on a per vehicle basis to light vehicles may be most appropriate. If they bear no

4 1997 Federal Highway Cost Allocation Study, Final Report, pV-24. Retrieved on June 21, 2010 from http://www.fhwa.dot.gov/policy/hcas/final/five.htm

relationship to motor vehicle use at all, then no particular allocation is better than any other and VMT is a reasonable allocator.

5.3 Railroad Safety Projects

These projects are primarily at grade highway-rail crossings. They constitute 0.4 percent of costs allocated in the 2009 study. The improvements benefit all road users in proportion to their use of the system.

These expenditures are for crossing arms and traffic control devices and may also include roadway work at the crossings. Therefore, they have incremental costs associated with axle weight. Additional study should be undertaken to determine if the roadway portions of these projects are significant.

Setting aside incremental costs of the roadway components of these projects, benefits are in proportion to use of the system. Therefore, VMT is logical for all aspects of these projects except road surface construction increments.

5.4 Fish- and Wildlife-Enabling Projects

These projects are mitigation projects that replace culverts to allow fish passage in streams passing under roads. They constitute 0.3 percent of costs allocated in the 2009 study.

Road users generally benefit in the sense that mitigating wildlife impacts is necessary to continued operation of the road system. There are no classes of road users that benefit more than others and it is unlikely that there would be incremental cost components to these projects. Even if design factors associated with accommodation of heavy vehicles on the roadway increased the cost of culvert replacement, the costs would be the same whether or not heavy vehicles used the road at the time of the mitigation projects.

Based on these considerations, VMT is the most logical way of allocating these costs.

5.5 Transportation Demand and System Management

Demand management includes a variety of techniques for reducing roadway congestion. There are two types of benefits resulting from these programs. First, all traffic benefits from reduced congestion. Second, passengers may benefit from the availability of an alternative means of travel, such as car pools. There are no incremental costs associated with these expenditures.

If benefits to congested traffic are emphasized, then charging these expenditures on the basis of congested PCE should be considered because that is the method of charging other expenditures intended to increase capacity.

If benefits to passengers are emphasized, then only light vehicles should be charged. This is the approach taken by the federal cost allocation study, which charges both demand management and transit costs to passenger cars.5 If this approach is taken, costs could be allocated to light vehicles either on a per-vehicle or a VMT basis.

5.6 Highway Planning

Planning constitutes 0.4 percent of expenditures allocated in the 2009 study. All classes of vehicles benefit from planning and there is no reason to believe that one class benefits more than others or that there are incremental costs associated with planning. Given the general benefit to all road users it makes more sense to charge these costs on a per mile or per vehicle basis to all vehicles.

5.7 Administration

Administration includes those administrative activities not directly associated with specific project and programs. These constitute 23.7 percent of costs allocated in the 2009 study and cover a wide variety of activities, including the ODOT director and transportation commission, region offices, financial

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5 1997 Federal Highway Cost Allocation Study, Final Report, pV-17-19. Retrieved on June 21, 2010 from http://www.fhwa.dot.gov/policy/hcas/final/five.htm

services, human resources, information systems, purchasing, contracting, communications, DMV functions not assigned to specific vehicle groups, and engineering functions not assigned to specific projects. These expenditures benefit road users through the sum of all programs carried out by ODOT and local agencies.

Currently all administration costs are allocated by VMT. However, because they are related to the overall program, including construction, maintenance, and all other activities, it may be more logical to allocate them as overhead in proportion to all other expenditures.

Alternatively, if administration could be subdivided into components such as DMV, general planning, and general administration, it may be that some components could logically be allocated by VMT or per vehicle while more general components are allocated as overhead. It is recommended that future studies subdivide administration and consider whether some components would more logically by allocated by means other than the VMT.

5.8 Impacts of Using Alternate Allocation Methods

A key question when considering alternative methods of allocating common or unallocable costs is, how much difference would the alternatives make in the overall distribution of costs between light and heavy vehicles? To answer this question, each cost category was evaluated to determine the shift in allocation between light and heavy vehicles that would result from the use of different allocators. The results are described in Table 2. These are not recommendations; they are presented only to illustrate the magnitude of potential changes.

These calculations show that changing the allocators for unallocable costs could shift costs as much as 6 percent from light vehicles to heavy. This shift would result primarily from allocating administration costs in proportion to all other costs rather than by VMT. Changing allocation methods for other costs would have a lower impact because they are generally a smaller percentage of total allocated expense and because the alternative allocators are closer to current allocators.

Table 2. Hypothetical Reallocation of Unallocable Costs

	Allocation		Total
	Light	Heavy	
Roadside Improvement and Maintenance			
Current method (VMT) (a)	$174	$19	$193
	90%	10%	
No change	$174	$19	$193
	90%	10%	
Bicycle and Pedestrian Projects			
Current method (congested PCE) (b)	$72	$7	$79
	91%	9%	
Alternate (light vehicle VMT)	$79	$0	$79
	100%	0%	
Railroad Safety Projects			
Current method (VMT) (a)	$15	$2	$17
	93%	7%	
Alternate (25% surface increments) (c)	$13	$4	$17
	78%	22%	
Fish- and Wildlife-Enabling Projects			
Current method (VMT) (a)	$10	$1	$12
	91%	9%	
No change	$10	$1	$12
	91%	9%	
Demand Mangement and System Management			
Current method (congested PCE)	$8	$2	$10
	79%	21%	
Alternate (light vehicle VMT)	$10	$0	$10
	100%	0%	
Planning			
Current method (VMT) (a)	$14	$3	$17
	91%	9%	
Alternate (per vehicle) (d)	$16	$1	$17
	95%	5%	
Administration			
Current method (VMT) (a)	$867	$90	$956
	91%	9%	
Alternate (percent of all other costs) (e)	$617	$340	$956
	65%	36%	
Total			
Currrent method	$1,161	$122	$1,283
	90%	10%	
Alternative methods	$920	$364	$1,283
	72%	28%	
Total as Percent of Total Allocations			**32%**
Shift	-$241	$241	
Shift as percent of total allocation	-6%	6%	

(a) VMT allocation is based on 2009 allocations of this work type
(b) Based on allocation for bicycle and pedestrian projects in 2009 study
(c) Assuming 25% is allocated as overall flexible surface reconstruction
(d) Vehicle allocation is from FHWA Highway Statistics 2008, Tables MV-1 and MV-9
(e) From 2009 Oregon Highway Cost Allocation Study, Exhibit 5-1

Issue Paper 8:

Treatment of Alternative-Fee-Paying (Subsidized) Vehicles

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1.0 Introduction

For more than 60 years, Oregon has based the financing of its highways on the principle of cost responsibility. Cost responsibility is the principle that those who use public roads should pay for them and, more specifically, that users should pay in proportion to the road costs for which they are responsible. Cost responsibility requires each category of highway users to contribute to highway revenues in proportion to the costs they impose on the highway system. 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 3 (a)(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.*

Under Oregon's existing highway taxation structure, some vehicles are exempt from certain fees or qualify to pay according to alternative-fee schedules. Recent Oregon Highway Cost Allocation Studies refer to these vehicles collectively as alternative-fee-paying vehicles. The two main types of such vehicles are publicly owned vehicles and farm trucks. Publicly owned vehicles pay a nominal registration fee and are not subject to the weight-mile tax. Many diesel-powered, publicly owned vehicles are also exempt from the state fuel tax. Operators of farm trucks pay lower annual registration fees than operators of non-farm commercial trucks, and most pay fuel taxes rather than weight-mile taxes when operated on public roads.

The reduced rates paid by certain types of vehicles means they pay less per mile and per year than they would if they were subject to full fees. The difference between what alternative-fee-paying vehicles pay and what they would pay if subject to full fees is termed the alternative-fee difference. The approach used in past Oregon studies is to calculate this difference for each weight class and to sum these amounts. The model reassigns the total difference (subsidy amount) to full-fee-paying vehicles on a per VMT basis. In essence, the model treats this amount as a common cost that all full-fee-paying vehicles share in proportion to the number of miles they travel within the state.

In preparation for this study, John Merriss of ODOT asked several questions, including the following:

- Does it make sense to continue the division of vehicles into those that are said to be full-fee-paying and those that are said to be alternative-fee-paying?
- How do other states' HCASs and the federal HCAS handle this issue (i.e., are there any lessons to be learned there)?
- Does the current division of vehicle types into those which are full-fee-

paying versus those that are alternative-fee-paying continue to make sense or does it need to be replaced with a different division?

- Assuming it continues to make sense to divide vehicle types used in studies by those that are full-fee-paying and those that aren't, how should the alternative-fee difference be allocated or assigned back to the full-fee-paying vehicle classes?

This paper is intended to provide a foundation for Study Review Team discussions about the treatment of alternative-fee-paying vehicles in the current and future Oregon Highway Cost Allocation Studies, under both traditional and efficient-fee methods. To facilitate the discussion, Jon Skolnik was asked to propose and justify an alternative to the approach used in recent studies and Mark Ford was asked to defend the status quo. The arguments they present in this paper do not necessarily represent their own opinions.

2.0 The Method Used in Recent Oregon Studies

We have not been able to determine the exact thoughts or intentions of those who developed the approach that has been used in recent studies, but the written record makes it clear that the approach was intended to be consistent with the cost responsibility principle. For the purpose of this paper, we will assume that the thinking was as follows.

Imagine that instead of charging some users lower fees, full fees were collected from all users and then subsidized users received a refund check drawn on the Highway Fund. The net result would be the same as under current-law fees. If that were the case, the share of revenues for each vehicle class would be the same as is now calculated for all full-fee-paying vehicles. The total amount disbursed as refund checks would be the same as the alternative-fee difference now calculated for all alternative-fee-paying vehicles. The cost of the refunds is treated as a common cost to the Highway Fund and is allocated on the basis of VMT to all full-fee-paying vehicles. The share of cost for each vehicle class becomes the share cost (inclusive of the allocated subsidy) for all full-fee-paying vehicles. The equity ratio for each vehicle class is the ratio of its share of revenue from full-fee-paying vehicles to its share of subsidy-adjusted costs for full-fee-paying vehicles.

3.0 The Method Used in Other Highway Cost Allocation Studies

The Federal Highway Cost Allocation Study and highway cost allocation studies by other states make no attempt to compute the amount by which alternative-fee-paying vehicles are subsidized. They count the costs imposed and revenues paid by all vehicles of each class. In the case of the federal study, this has almost no effect on equity ratios because very few vehicles are exempt from federal user fees. The largest class of alternative-fee-paying vehicles at the federal level, limited-use highway vehicles, operate primarily off road and contribute little to highway costs.

All of the other state highway cost allocation studies we examined treated alternative-fee-paying vehicles in the same way as in the federal study. That is, they ignored the fact that some vehicles in a weight class paid lower fees than others and just tallied up the amount actually paid by all vehicles in that class.

The federal approach is simpler to implement because it doesn't require determining the amount of the subsidy, nor does it require apportioning VMT between full-fee-paying and alternative-fee-paying vehicles in each vehicle class.

When subsidies are non-trivial, as in Oregon, the federal approach results in equity ratios that indicate equity when the fees paid by full-fee-paying vehicles within a weight class fully cover the cost of subsidies to alternative-fee-paying vehicles within that same weight class. In contrast, the Oregon approach shifts the cost of subsidies to all vehicle classes in proportion to VMT.

4.0 An Alternative Approach to Consider

A different approach would be to consider only the costs imposed and revenues paid by full-fee-paying vehicles when calculating equity ratios. Equity ratios would indicate equity when the full fees match the share of cost to the share of revenues for vehicles that pay the full fees. The difference between this approach and Oregon's approach is that it does not assume that the cost of the alternative-fee difference is a cost to the Highway Fund. The Highway Fund gets what it gets (from user fees, federal funds, and bond sales) and spends what it spends (on ODOT, transfers to local governments, and bond repayment). Equity ratios do not require that expenditures equal user-fee revenues, and they aren't equal in any case, even after adding in the alternative-fee difference as a cost.

Relating this approach back to the story about the imaginary world with refund checks instead of alternative fees, under this approach, the imaginary refund checks would be drawn on the General Fund rather than the Highway Fund. The rationale for funding them from the General Fund would be that the public purposes served by the subsidies benefit the general public and are not specific to full-fee-paying highway users.

5.0 Argument for the Alternative Approach

The suggested approach is to compare the full-fee vehicle user revenues to the full-fee vehicle user responsibilities. The full-fee cost responsibility would include only those costs attributable to full-fee vehicles. This method of calculating equity ratios would result in full-fee vehicles paying their true user cost, the principle on which Oregon has based the financing of its highways for more than 60 years.

Alternative-fee-paying vehicles often receive a discount or subsidy because they provide a benefit to society in general or some subset of society. However, just because such a subsidy is provided to a needy or deserving segment of society, it does not follow that taxing highway users is the most equitable or efficient means of collecting that subsidy. In order for such a subsidy to be properly included in the calculation of equity ratios and future tax rates, the benefit provided by the subsidy should satisfy the user-pays principle. For example, the cost of a government truck filling potholes, plowing snow, or sweeping the street can be categorized as a road cost that users would properly pay for. On the other hand, if an activity or cost benefits non-road users, the cost of the subsidy is not a true user cost and, under the user-pays principle, highway users should not fully subsidize such costs.

There are five groups of alternative-fee-paying vehicles: farm, flat fee, charitable and non-profit, public and school, and tow trucks. Public and school vehicles receive the majority of the subsidy amount at 65.3 percent, farm vehicles receive 21.4 percent and flat fee vehicles receive 11.2 percent. Flat fee vehicles are log trucks, sand and gravel and chip trucks that pay a flat monthly fee based on declared combined weight of the vehicle and commodity in lieu of the weight-mile tax. Charitable and non-profit vehicles and tow truck vehicles receive a combined 2.1 percent of the total subsidy.

The remainder of this section assesses the responsibility of full-paying vehicles to subsidize each type of alternative-fee-paying vehicle. A close examination of each of the five types concludes that only a small fraction of the current subsidy cost can be classified as true user costs, and therefore, full-paying vehicles appear to paying more than their fair share of responsibility.

5.1 Farm Vehicles

Trucks that are titled in Oregon and used for a certified farm operation qualify for farm registration status. They benefit from a low truck registration fee and they do not pay the Oregon road-use tax (weight-mile tax). The following is the Oregon DMV definition of farm-related activities and vehicles:

> *A "farming operation" is a farm, orchard, or ranch that produces agricultural commodities, products, and/or livestock. Farm-registered trucks are generally used to haul agricultural commodities, products, or livestock.*

Under current Oregon highway cost allocation, the reduction in fees for farm vehicles are subsidized by full-paying vehicles based on vehicle class VMT. In general, the current system subsidy-allocation system is rationalized on the basis that most vehicles paying reduced fees are providing a public service or societal benefit and should be subsidized by non-subsidized highway users in relation to their use of the system. There may be a valid argument that farm vehicles maintain an American ideal.

The definition of farm operations and the use of farm vehicles do not explain how that good provides a benefit to highway users. More intuitively, it appears that any public benefit provided by farm vehicles should be shared by the general public. This could be achieved by deriving subsidy funds from the general Oregon tax revenue fund.

5.2 Flat-Fee Vehicles[1]

Under existing Oregon law, log, wood chip, and sand and gravel haulers have the option to pay monthly flat fees in lieu of the weight-mile tax. The various flat-fee rates are set so that carriers paying them should, on average, pay the same amount as they would under the mileage tax. The purpose of the flat fee was to reduce record keeping and reporting requirements for the hauling of commodities that were more seasonal, short haul, and often a mix of taxable and nontaxable (i.e., not public road) miles. While there is no intention to subsidize flat-fee vehicles, in practice, some vehicles may be subsidized. A flat fee system gives a significant tax benefit to users of the system who travel significantly more than the average number of miles a year for their class of truck. For example, inadequate payment levels in one allocation period could be collected in subsequent periods.

Log, wood chip, and sand and gravel haulers do not provide a unique benefit or service to road users. The only discernible benefit to society is the reduced administrative cost to the DOT. Therefore, not only should full-paying vehicles be exempt from subsidizing flat-fee vehicles, but the general public should be exempt as well. If revenues for flat-fee vehicles fall short of projected levels, increases in the flat fee should be implemented rather than increases in the fees of other vehicles.

5.3 Charitable and Non-Profit Vehicles

Charitable and non-profit vehicles are also subsidized in part by full-paying vehicles. The argument can be made that these vehicles provide a public benefit. In many cases, the direct beneficiaries of this societal benefit are often not financially able to pay for these services, or the government may see a societal benefit from increasing these activities. With this in mind, it appears rational to spread this subsidy across the general public in additional fees or for the state government to pay for it through a general revenue fund. Charitable and non-profit vehicles are by no means limited to highway and road-related services and usually do not

[1] The intent of this issue paper was to discuss the rationale behind the treatment of alternative-fee paying vehicle classes in the Oregon Highway Cost Allocation Study. In previous studies, flat-fee vehicles were categorized as alternative-fee paying vehicles. After discussions in Study Review Team meetings for the 2011 Study, it was decided that flat-fee vehicles should no longer be treated as alternative-fee vehicles because, *as a class,* flat-fee vehicles are not necessarily "subsidized" by paying flat fees rather than the weight-mile tax. This issue paper was written prior to that decision and refers to flat-fee vehicles as a class of alternative-fee paying vehicles because that is how they were treated in past Oregon Highway Cost Allocation studies.

provide services in the highway domain. If the cost allocation is based on the user-pays principle, full-paying vehicles should not be responsible for this alternative-fee difference.

5.4 Tow Trucks

Tow truck service is primarily highway and road related. The beneficiaries of these services are highway users, both for individual accident victims who need their vehicles moved and for all road users who benefit from better traffic flow. It is reasonable for full-paying vehicles to pay at least some of the alternative-fee difference, at least the portion that benefits all road users.

5.5 Public and School Vehicles

In the case of public and school vehicles there is a strong case that a societal benefit is being provided. However, as with the other types of alternative-fee-paying vehicles, it is not apparent that road users should cover the potions of the subsidy not related to user costs. Ambulances service road-accident victims, police monitor speeding to keep the roads safe, road-cleaning crews keep the highway systems clean, and parking enforcement ensures that roads are clear during rush hour. In addition, public transit and school buses may reduce the number of vehicles on roads and therefore increase traffic flow for all vehicles.

It is also the case, however, that ambulances serve people at their homes (including the elderly, who are less likely to be road users); the domain of fire trucks is not limited to road accidents; police are often responding to non-highway-related activities, such as theft and domestic disputes; school busing is a service that primarily benefits parents and guardians in time saved; and transit vehicles partially benefit non-road users. Therefore, it appears that public- and school-vehicle subsidies are not purely user based.

The fact that many non-road users benefit from the services of these alternative-fee-paying vehicles gives reason to lessen the alternative-fee difference paid by full-fee paying vehicles and increase the amount covered by a general revenue fund.

This examination of alternative-fee-paying vehicles reveals that few of the subsidies truly benefit road users in a way that satisfies the user-pays principle. Examples that do satisfy this principle include police vehicles involved in traffic duties, state and local vehicles involved in street sweeping, and the activities of transit buses in reducing congestion. However, non-road-related general societal benefits overshadow these activities. Flat-fee vehicle subsidies and subsidies to farm vehicles, which together account for 32.7 percent of the alternative-fee difference, do not provide any direct benefit to general road users. Only small portions of public vehicles, school vehicles, and tow trucks provide services to general highway users. Therefore, at least some of these subsidies should come from the either the General Fund or some set of similar sources.

6.0 Argument for Keeping the Status Quo

6.1 Explicit Consideration of Subsidies is Good Public Policy

A fundamental premise of cost responsibility as practiced in Oregon is "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." If for some purpose of public policy certain vehicles do not pay their share of costs, it is valuable for policy makers to understand the level of subsidy being granted to these users.

6.2 The Oregon Approach is More Equitable Than the Federal Method In the Allocation of Expenditures to Alternative-Fee-Paying Vehicles

The fundamental concept of cost responsibility is that those who benefit from the expenditures pay for them in proportion to the costs that are incurred for their benefit. To the extent that some of the costs associated with alternative-fee-paying vehicles are covered by other users, there are three useful questions to be asked:

- Do any classes of full-fee-paying vehicles or vehicle operators benefit more than others from the activities being subsidized?
- To the extent that particular classes of full-fee-paying vehicles benefit from the subsidized activities, does one or another class bear more responsibility for these costs?
- Does the Oregon method or the federal method of allocating these costs better reflect the answers to the first two questions?

Several classes of alternative-fee-paying vehicles probably generate benefits to full-fee vehicles, such as school buses, which may reduce congestion since there are fewer light vehicles used to transport children to school; transit buses, which reduce congestion in urban areas; state and local agencies, which maintain roads; and tow trucks, which serve road users. It appears that about 60 percent of subsidies may benefit full-fee vehicles in some way.

For school buses, state and local government vehicles, and tow trucks, some component of the subsidy cost may be related to vehicle class or size and weight. For instance, some state and local vehicles are involved in road maintenance, for which heavy vehicles have a larger per mile responsibility. However, these components would likely be very small compared to the overall level of subsidy to alternative-fee-paying vehicles.

Because the federal methodology simply ignores vehicles that do not pay full fees, the results would distort cost allocation calculations if used in Oregon. For instance, if transit buses, farm trucks, and other vehicles using heavy axles were left out of the calculations, the allocation of surface maintenance and preservation costs would be distorted. The distortion would not be large, with alternative-fee-vehicles constituting only 3.2 percent of total VMT and heavy vehicles constituting only 6.4 percent of the allocated alternative-fee difference. However, it is better to compute cost allocation accurately using all available information rather than ignoring these vehicles because they do not pay full fees.

In conclusion, only a small proportion of subsidized costs have any component related to class or weight of full-fee-paying vehicles. Two components, school buses and transit buses, may generate benefits that are related to mileage. Thus the Oregon method of calculating and then reallocating subsidies by mileage is logical and clearly more equitable than allocating in proportion to overall cost responsibility for all other road costs.

6.3 The Federal Approach Deals With a Different Situation

With respect to tax exemptions, there are three important ways in which the Federal Highway Cost Allocation Study differs from the Oregon study. First, the federal study notes that, in regard to exemptions from user fees, "The broadest category of current exemptions is for minimal highway usage. The HVUT [heavy vehicle use tax] is assessed on an annual basis and has an exclusion for those vehicles which use the public highways less than a minimal amount during the year. Since the HVUT does not vary with increasing mileage, those vehicles that rarely use the public highways are relieved from payment of the HVUT." The study also notes other categories of exemptions, especially government vehicles and transit buses. Many of these vehicles are used most heavily on the local road system.

Second, since the federal cost allocation study is concerned with allocation of Federal Highway Trust Fund expenditures, which are predominantly on higher level road systems, the distortion created by excluding these vehicles is probably less than would be the case in Oregon.

Finally, the federal study makes the claim that data are not available to calculate the value of revenues foregone because of exemptions or to allocate cost responsibility to the exempt vehicles.

Within this context it may be logical to leave these vehicles out of the study. This logic would not hold in Oregon, however. First, only a minority of the alternative-fee vehicles are granted this status because they operate off the road system. The largest group of those vehicles are flat-fee vehicles for which a subsidy is not intentional.

Second, the Oregon study is concerned with the maintenance and construction of local, state, and federal aid highways. This being the case, the impact of transit and other alternative-fee vehicles and the costs that should be allocated to them is more significant.

Third, Oregon has been able to collect or estimate usage data for alternative-fee paying vehicles, making the calculation of the impacts and the implicit subsidies of these vehicles possible.

6.4 Oregon's Method is Superior

This analysis concludes that the Oregon method of allocating costs of alternative-fee-paying vehicles is superior to the federal method, which ignores their impact and thereby implicitly allocates their costs to other vehicles in proportion to their responsibility to all other costs. The Oregon method of first calculating the full responsibility of alternative-fee-paying vehicles and then allocating these cost on a per mile basis

- Is a better approach to public policy
- Is more equitable
- Avoids distortions in the calculation of responsibility, and
- Is more appropriate to the Oregon context

7.0 Analysis of the Effects of Different Methods

The following table summarizes the effects of different methods of dealing with alternative-fee-paying vehicles on equity ratios in the 2009 Oregon Highway Cost Allocation Study.

Equity Ratios by Summary Weight Class	Oregon Method	Alternative Method	Federal Method
Light Vehicles	0.9915	0.9952	1.0124
All Heavy Vehicles	1.0173	1.0097	0.9775
10,001 to 26,000	1.1576	1.1514	1.0228
26,001 to 80,000	1.0655	1.0575	1.0271
78,001 to 80,000	1.1234	1.1149	1.1327
80,001 to 104,000	0.8278	0.8212	0.8161
104,001 to 105,500	0.9210	0.9136	0.9159
105,501 and up	0.5932	0.5878	0.6027

Issue Paper 9:

Financing Trends: Local Agency Trends

Mark Ford, Mark Ford and Associates, LLC

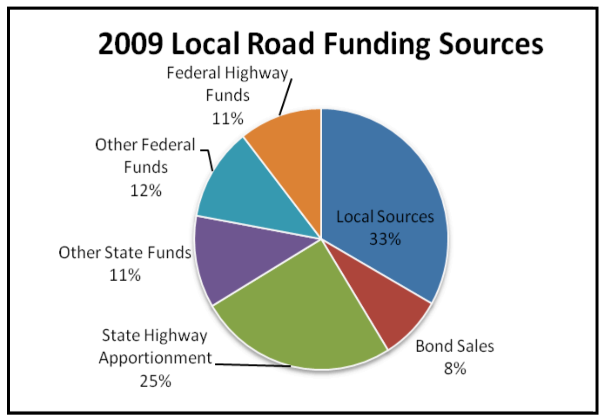
1.0 Introduction

The purpose of this paper is to examine trends in local road financing in Oregon and identify any implications for highway cost allocation. In particular, the paper explores the potential cost-responsibility implications of local funds (e.g., whether these funds are included in cost allocation) and the fungibility of local funds for state or federal dollars. The paper is presented in six sections:

- Section 1.0 provides background on the sources and uses of local road funding.
- Section 2.0 reviews trends in local road funding that may affect cost responsibility.
- Section 3.0 provides a general evaluation of the degree to which current local sources reflect cost responsibility principles.
- Section 4.0 evaluates fungibility of local funds in relation to cost responsibility calculations in the Oregon Highway Cost Allocation Study.
- Section 5.0 considers future possibilities for local road funding.
- Section 6.0 provides conclusions regarding cost responsibility and fungibility.

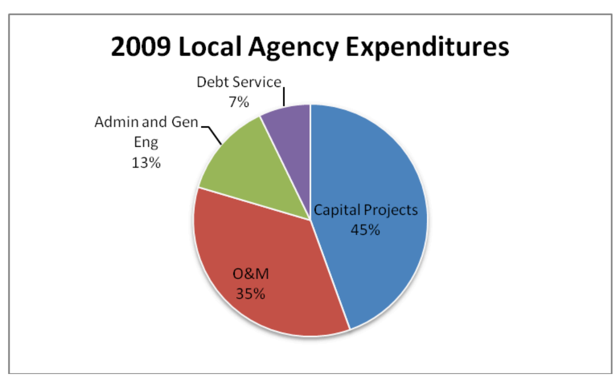
The current structure of local agency finance is illustrated in Figures 1 and 2, based on the 2009 City-County Roads Finance Survey. Total local road funding, including federal highway funds, spent on local roads was approximately $900 million in 2009. Of this amount, local sources and local bond sales were more than 40 percent of the total, with the remainder being a combination of federal and state sources. Local apportionment of state highway funds supplied 25 percent of revenue used by local agencies, and federal highway funds administered through the Oregon Department of Transportation (ODOT) added another 11 percent. Other federal sources were predominantly federal timber

Figure 1



Source: Mark Ford and Associates based on 2009 Local Agency Survey plus estimated Federal Highway Fund, local expenditures.

Figure 2



Source: Mark Ford and Associates based on 2007 Local Agency Survey plus estimated Federal Highway Fund, local expenditures.

receipts that went to certain counties. More will be said about this source later in the paper. Bond sales are local general obligation or revenue bonds backed by local revenue sources.

Local agency expenditures are shown in Figure 2. Again, they totaled approximately $900 million in 2009. Nearly half of expenditures were for capital projects and more than one third of expenditures were for maintenance and operations. Administration, engineering, and debt service accounted for the remainder.

2.0 Local Revenue Trends

2.1 HB 2001 and State Highway Fund Apportionments

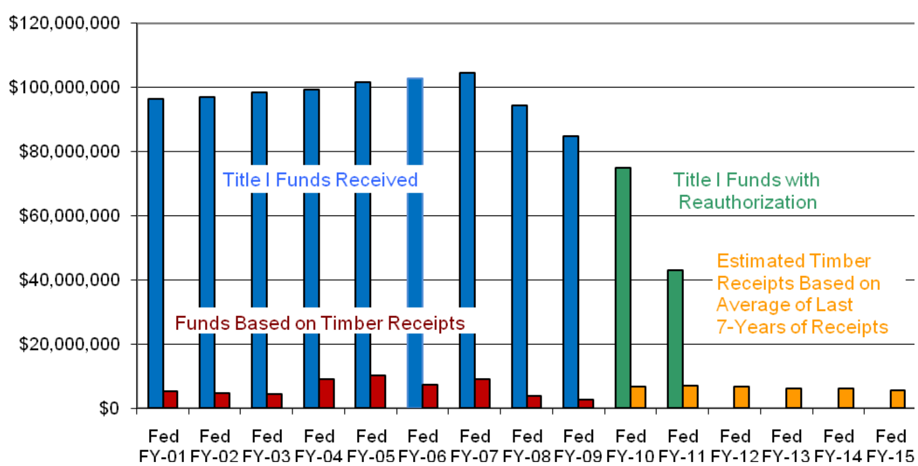
State highway fund apportionments will increase as a result of House Bill 2001. ODOT revenue forecasts show an increase of approximately $133 million per year starting in FY 2011. Of this revenue, 20 percent will be distributed to cities based on population and 30 percent to counties based on vehicle registrations.

2.2 Federal Timber Receipts

While highway fund apportionments are increasing, federal timber revenue is in decline. Of the three major timber revenue sources available to counties, two have declined to the point that they no longer provide any revenue for roads.[1] Only the U.S. Forest Service continues to provide funding dedicated to roads. Figure 3 shows the amount of U.S. Forest Service revenue going to county road funds in recent years and forward through 2015. The short bars across the bottom of the chart show receipts that would result if payments were based strictly on harvest. The taller bars through FY 2009 show receipts based on federal timber compensation payments instituted after restrictions on logging dramatically reduced timber sales revenue.[2] After FY 2009, federal timber compensation is being phased out so that, beginning in federal FY 2012, counties will receive only revenue based on timber sales. This will represent a reduction of more than $90 million per year cut from peak payments of $100 million per year.

The revenue decline resulting from this change is more than counties will receive from increased apportionments of state highway funds resulting from HB 2001. This presents a particularly difficult problem for small rural counties who were dependent on timber revenue and will receive a relatively small share of new

Figure 3
Total USFS Revenue to Oregon Counties Road Funds



[1] These two sources are the Oregon and California Lands (O&C) Revenue and Bureau of Land Management (BLM). Both have declined dramatically and all remaining revenue going to counties is being used for general purposes and school finance. A small amount of BLM revenue shows up as county revenue, but this is compensation for road building, not new revenue.

[2] Sources include "Westside" Spotted Owl Guarantee from 1991 to 2000, Secure Rural Schools and Communities Guarantee (SRSCG) from 2000 to 2006, and extensions of SRSCG from 2007 through phase-out in 2011.

apportionments. The following counties will likely experience a net loss of revenue even after increases in apportionments resulting from HB 2001: Baker, Cook, Curry, Douglas, Grant, Harney, Hood River, Jefferson, Klamath, Lake, Lane, Lincoln, Linn, Tillamook, Union, Wallowa, Wasco, and Wheeler.

2.3 Development-Based Special Levies

Another trend significant to local agencies is the tendency to increase reliance on special levies rather than general fund revenue or local road use taxes. Figure 4 shows the various sources of the more than $260 million of locally generated revenue in 2009. The largest single category of local funds is special assessments, including system development charges, special assessment districts, street utility fees, and other assessments, which now account for one third of revenue collected at the local level. If not for declines in 2009 due to the recession this source would be even larger. Most of this revenue is dedicated to capital projects and repayment of bonds. Meanwhile, general funds and general property taxes have been declining. Local gas taxes, while important to some jurisdictions, are a small portion of overall local funding.

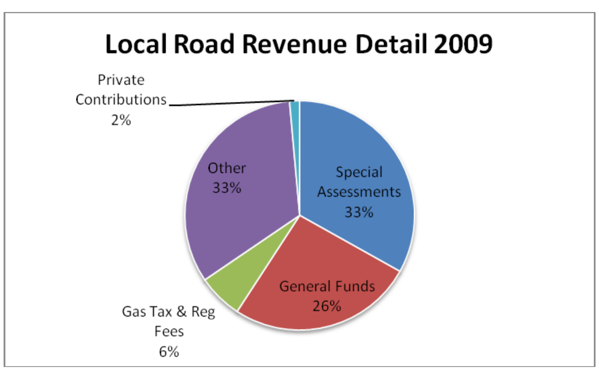
One of the problems with special levies and tax measures is that they vary significantly between jurisdictions, creating substantial differences in resources availability. For instance, gas tax fees are levied in only three counties and half a dozen cities. Although they benefit those jurisdictions, they do not provide a consistent source of local revenue. Special levies are often based on system development charges or special development districts that depend on economic development to fund roads. These are only realistic in growing areas.

3.0 Cost-Responsibility Aspects of Local Sources

Oregon's formal evaluation of cost responsibility relates solely to motor vehicles and road user fees. Based on this approach, most local road revenue is outside the normal revenue attribution procedures because most local road revenue sources are not directly attributable to vehicle classes. As shown in Figure 5, only 15 percent of the approximately $260 million of local road revenue is related to charges on vehicles. These sources include local gas tax and vehicle registration fees and other vehicle-related fees. The largest portion of other vehicle-related fees is parking fees and fines, which relate directly to use of urban streets.

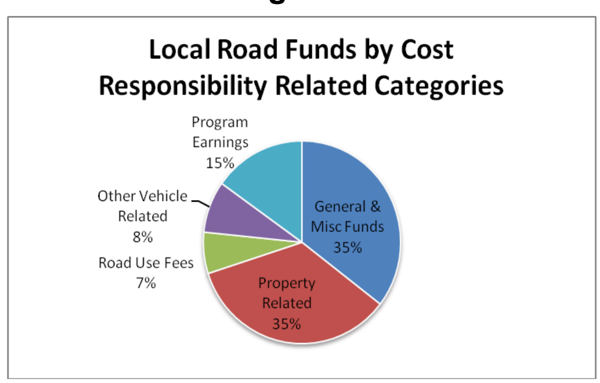
A closer look at other categories reveals two aspects of local fees that relate to cost responsibility in general or indirect ways. Property-related fees in Figure 5 include system development charges (SDCs), traffic

Figure 4



Source: Mark Ford and Associates based on 2009 Local Agency Survey

Figure 5



Source: Mark Ford and Associates, based on 2009 Local Agency Survey. Does not include bond sales.

impact fees, and transportation utility fees, all of which are intended to compensate for additional costs on the road system generated through development and use of property. SDC and utility fees are calculated based on projected traffic generation from the property. Other property-related assessments also have an indirect connection with road development in that property owners can be direct beneficiaries of road improvements when they increase accessibility and property values.

Program earnings shown in Figure 5 include franchise fees that are charged by cities to utilities for use of public right-of-way. Though not a cost responsibility consideration related to road users, franchise fees are directly related to benefits received from public investments in roads.

Finally, a large portion of local general funds continue to be property tax assessments. Again, there is a general relationship between benefits property owners receive from road development as reflected in property values.

In conclusion, local funding for roads does not include significant amounts of user fees and therefore does not translate well to the traditional Oregon highway cost allocation methods for user-class revenue attribution. However, because of the heavy reliance on property-related sources, some of which are directly tied to traffic generation, there is a general relationship between local road funding and benefits received from that development.

4.0 Fungibility of Local Revenue Sources

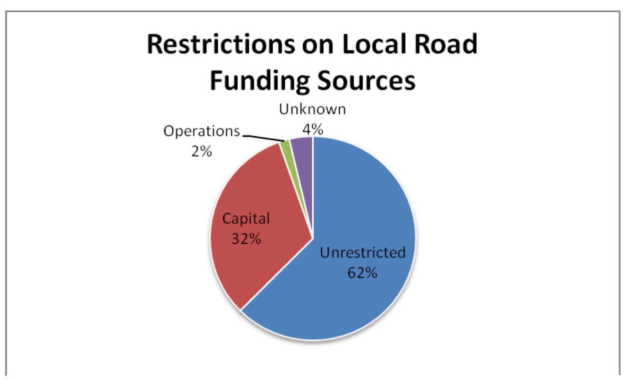
A key question for cost allocation studies is the degree to which various sources of state, local, and federal sources are fungible so that cost allocation studies can consider expenditures without regard to the source of revenue.

In general, local special levies, bond issues, and federal highway funds are restricted to capital projects. Figure 6 shows a different division of the $900 million in local road funding sources for 2009. As shown, approximately 32 percent of local road funding sources, including federal aid, are restricted to capital projects.

Although a large portion of local funds are restricted to capital projects, two factors lead to the conclusion that most local sources are in fact fungible. First, the amount of local expenditures on capital projects (45 percent of expenditures in Figure 2) exceeds the expenditure requirements (32 percent in Figure 6), even considering that some of the "unrestricted" revenue is used to match federal funds. The implication is that local agencies are spending unrestricted funds on capital even when not required to do so. Second, many of the federal funds are being spent on preservation projects for which local sources would otherwise have to be spent. Such projects remain important even if funds are inadequate to meet growing maintenance and operations needs.

On the other hand, bonded debt and special levies continue to be restricted to projects that by nature are different from the general road program. Most special levies and bond issues are for construction projects related to new development, for which general road revenue is not spent, and are different from the expenditures of the road and street programs in general. As a result, these sources may continue to be

Figure 6



Source: Mark Ford and Associates based on 2009 funding sources identified in Local Agency Survey. Includes FHWA expenditures on local roads. Does not include bonds or local interagency payments.

regarded as non-fungible and left out of the cost allocation calculations.

5.0 New Local Funding Options

5.1 Tolls and Congestion Charges

New funding options being discussed at the state and local level are tolls, congestion pricing, and mileage fees. None of these have yet been implemented in Oregon and it is unclear how they would affect local funding. Tolls are relevant only for high-volume routes for which there are limited alternatives available. None of the opportunities for toll roads identified in Oregon has included local facilities.

There are various forms of congestion pricing being considered. If implemented as toll road pricing, this funding option would be irrelevant to local roads. If introduced as cordon or area prices, congestion pricing could have more relevance to local roads in congested areas.

5.2 Mileage Fees

A more promising future option is the introduction of mileage fees that can be adjusted by area. Oregon's mileage fee pilot demonstrated the capability to collect fees based on actual mileage and to distinguish mileage by area and time of day. If a general system were introduced statewide or nationally this could provide the opportunity for cities and counties to introduce local fees to be collected along with state fees and returned to the local area. The ultimate relevance to local areas would depend on what restrictions were placed on local governments' abilities to piggy-back onto the system.

5.3 Development-Based Levies and Street Utility Fees

Until mileage fees are introduced on a significant scale, two sources are likely to increase in use at the local level. One is development-based levies that can be used to finance new construction associated with growth. These have already been discussed.

Another approach to local funding being pursued by several cities is the use of street (or transportation) utility fees to fund maintenance. Currently, 19 Oregon cities use this source of revenue, which is levied on different types of property based on estimated traffic generation. The fees are collected with other water and sewer fees. Unfortunately, street or transportation utility fees are not available to counties because they lack a collection mechanism. Though not strictly a road user fee, there is a direct connection with transportation and the revenue collected could, if desired, be attributed within the cost allocation framework.

6.0 Conclusions

With regard to cost allocation and revenue attribution for the purposes of the Oregon Highway Cost Allocation Study, there are two general conclusions from this analysis. First, city and county road funding is becoming more user based. State highway fund apportionments are increasing while timber revenues and general funds are declining. Introduction of mileage fees would continue that trend. The increased use of street utility fees, system development charges, and development-based special levies reinforce aspects of cost responsibility even though they do not charge vehicles directly.

Second, current cost allocation procedures with regard to allocation of local costs and attribution of local revenues are still appropriate. With regard to fungibility, special levies and the bonds that they support are not fungible, whereas all other local revenue and expenditures, including local federal aid, are fungible.

Issue Paper 10:

Effects of Toll Roads and Public-Private Partnerships

Michael Lawrence, Jonathan Skolnik, and Scott Williamson, Jack Faucett Associates

1.0 Introduction

Revenues come from a variety of taxes and fees. There are two basic approaches to attributing revenues to user classes. One is to apply the fee schedule to estimated numbers of taxed units of activity by each user class. This is how revenues from the weight-mile tax (WMT) are estimated. The tax is per mile and the rate varies with vehicle weight (and number of axles for the heaviest WMT vehicles). The number of taxed miles for each weight class is estimated and the appropriate rate applied to estimate revenue from that weight class.

This paper introduces two revenue mechanisms, public-private partnerships (PPPs) and tolling, that are widely utilized around the United States and in many other countries. It then summarizes the types and characteristics of toll-road PPPs, which typically allow governments to shift the bulk of a project's cost to the private sector in return for the rights to toll revenues. It next describes the impacts of tolling and PPPs on the highway cost allocation process. It concludes by suggesting alternative methodologies for including PPPs and tolling in Oregon's cost allocation framework.

2.0 Public-Private Partnerships Overview

PPPs are gaining an increasing presence in the process of planning and implementing public infrastructure projects. Faced with pressing needs and tightening budgets, governments are considering the extent to which novel approaches to infrastructure procurement can serve public needs better than the traditional public sector spending methods. Some have looked to the private sector for help. Such help can come in a variety of forms, such as quicker project turnaround, alternative forms of project financing, or private sources of funding for some or even all of a project's construction costs.

Transportation agencies face significant challenges and risks in their task of procuring new infrastructure to meet ever-increasing transportation demands. Projects come with high up-front costs that strain budgets and financing resources, as well as uncertain long-term costs for maintenance and repair in the decades to come.

PPPs present the possibility that private-sector involvement might alleviate these concerns by reducing the risk faced by the government as well as easing the fiscal and financial strain. States consider PPPs for a variety of potential benefits that vary with the nature of the project and the contract:

- Accelerated construction times
- Transfer of financing obligations to the private sector (potentially freeing public financing for other needs or enabling a project when public financing faces hurdles)
- Transfer of operations, maintenance, and oversight obligations, both administrative and financial
- Transfer of long-term financial risks, such as maintenance and repair cost uncertainty, toll revenue uncertainty, finance cost uncertainty, and many other risks
- The potential for a large infusion of immediate cash in exchange for the transfer of a revenue stream to the private sector

3.0 Tolling Overview

Tolling refers to charging a direct fee to each user of a segment of road on a per use basis. As a revenue stream, tolling can be implemented both independently of PPPs and as part of a PPP agreement. The government entity in charge of a given facility usually receives legislative approval to charge a toll to vehicles. Tolls can vary based on the length of a trip (such as on the Pennsylvania Turnpike) and the size and/or weight of each vehicle as well as time of day or current traffic levels. Thus, a tolling mechanism is an effective tool for allocating costs differentially based on both type of vehicle and extent of roadway usage.

Though Oregon currently has no toll roads, the state has extensively explored tolling in recent years. In 2007, Oregon's legislature directed the development of policy recommendations for future tolling projects. In response, the Oregon Department of Transportation (ODOT) commissioned a series of white papers and a study of the prospects of tolling in the state.[1] In 2009, Oregon passed a mandate in the 2009 Jobs and Transportation Act requiring that ODOT develop

4.0 Tolling and Public-Private Partnerships

The creation of a tolling PPP involves issuing a concession to a private entity (usually a consortium set up specifically for the PPP agreement), allowing it to collect tolls on a road over a long period of time – 30 to 75 years or more. Tolling PPP agreements come in three main varieties:

- New toll roads
- Commuter corridor expansions
- Operations and maintenance of existing facilities

In the case of a yet-to-be-built facility, the private entity typically agrees to secure financing for most or all of the new facility and assumes responsibility for the costs of operating and maintaining the facility. The funds to pay off the debt and provide the operator's profit are drawn from the tolling revenue.

Similar and more common in the United States is the scenario involving the expansion of a commuter corridor. The private entity takes on most or all of the cost of the expansion project and receives in return the right to collect tolls on at least some lanes (usually the "express" lanes) of the project.

The third variety involves an existing facility. In this case, the private entity typically agrees to pay the state a large up-front payment at the beginning of the concession. In return, the entity receives rights to the tolling revenue stream. In two recent high-profile PPP agreements, a private consortium agreed to pay $1.8 billion and $3.8 billion in up-front payments respectively for the rights to toll revenues on the Chicago Skyway and the Indiana Toll Road. That cash infusion allowed immediate spending on needs by both the City of Chicago and the State of Indiana. However, tolls paid by motorists doubled on each road and are subject to annual inflation-indexed increases for the life of the leases (99 and 75 years, respectively).

Despite their ability to significantly alter the timing, financing, and uncertainty of project costs, PPP projects are not "free." They present large costs of their own, through either payments from the government or tolls and fees charged directly to users. In addition, concerns about a private entity's long-term viability and its dedication to quality control necessitate careful analysis of any project to determine if a PPP approach is suitable. (Some tolling PPPs have resulted in bankruptcy when traffic volumes fell too low and the operators could not find more financing; expensive government

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[1] Oregon Department of Transportation. Tolling White Papers – Background. Retrieved on June 25, 2010 from http://www.oregon.gov/ODOT/TD/TP/Tolling_Background.shtml

interventions followed.) Also, the granting of a toll-revenue concession to a private firm deprives the state of a long-term cash revenue stream for the duration of the contract. Because of these potential setbacks, governments around the world with experience in PPP procurement have developed approaches to help determine whether or not a PPP is cost effective and appropriate.

5.0 Oregon's Interest in Toll-Based PPP Highway Projects

Oregon shares the circumstances of many other states. Its most recent long-term transportation plan document projected that the state would face a shortfall of $5 billion against necessary transportation improvement projects by the year 2030. Congestion on commuter corridors is high, and communities are outgrowing the facilities that serve them.

Oregon has considered PPPs as a strategy to help provide for the public's transportation needs. State legislation, passed in 2005, gave ODOT the authority to enter into PPP agreements covering most aspects of transportation construction and maintenance.[2] Pursuant to that, the Oregon Transportation Commission (OTC) commissioned a $20 million study of the projected feasibility of PPP contracts for three projects:

- Sunrise Corridor project (new construction of a 5-mile connector)
- Newburg-Dundee project (new construction of an 11-mile highway)
- I-205 expansion project (expansion of a congested interstate highway)

The study determined that the I-205 expansion could feasibly be procured through a tolling-based PPP but that the Sunrise Corridor project could not, because low projected traffic volumes would not produce enough tolling revenue to cover the high construction and operation costs.[3]

As of June 2010, Oregon had not entered into a PPP agreement in the transportation sector. Other states around the country have entered into a variety of agreements covering new, expanded, and existing facilities. Many states now have enabling legislation and initiatives to explore PPP opportunities. Most projects so far have been free of major problems, but not all: the South Bay Expressway outside of San Diego has suffered from low utilization, and toll revenues were insufficient to support the private operator's debt financing obligations. The operator filed for bankruptcy within three years of opening the road.[4]

6.0 Issues Regarding PPP Highway Data Availability and the Cost Allocation Processes

To ensure that data are available to inform cost allocation processes, governments should require data from PPP projects. Although it is true that some PPP projects transfer the costs of construction, operation, and maintenance to the private sector, state DOTs still have an interest in understanding costs and usage over the whole system. Furthermore, PPPs may transfer costs but do not necessarily transfer ownership – they simply establish private operations of public facilities. Finally, and most importantly, users of PPP projects still provide revenue to public

[2] Pikiel and Plata (2008, August). A Survey of PPP Legislation Across the United States. Global Infrastructure. Retrieved on June 23, 2010 from http://www.ncppp.org/resources/State%20PPP%20Legislation%20Survey_2008.pdf

[3] Oregon Office of Innovative Partnerships and Alternative Funding. Archived Project Information. Retrieved on June 23, 2010 from http://www.oregon.gov/ODOT/HWY/OIPP/inn_archive.shtml

[4] Saskal, R. (2010, March 30). California P3 Files for Chapter 11. The Bond Buyer. Retrieved on June 24, 2010 from http://www.bondbuyer.com/issues/119_309/California_P3_Files_Chapter_11-1010232-1.html

transportation funding sources, such as fuel taxes, vehicle sales taxes, and licensing and registration fees. Understanding these contributions is necessary to accurate cost allocation.

Despite this need for user data, the operators of existing express lane, variable pricing, and tolling projects have not, to date, tended to maintain detailed volume and toll activity data. In some cases, this occurs because concerns about privacy have resulted in business operation rules that require deleting or aggregating trip-level data for the users of the tolled lanes. In other cases, the performance criteria of interest were not developed as part of a full benefit cost appraisal, which considered more practical criteria such as the sufficiency of the project revenues to underwrite the tolling implementation.

This is not surprising because many early projects were intended to demonstrate the variable pricing principle, and not necessarily to achieve the greatest societal benefit. The goal was to familiarize the public with pricing as a concept, with no pretense that the project was optimally designed in some broader sense. The availability of data is spotty and often not maintained in comparable forms. Many of the older express lane projects lack vehicle counter hardware in the general-purpose lanes, making it difficult to assess total volumes, or forcing reliance on counters operated by other authorities. The coverage and up-time reliability of these counting systems is not necessarily useful for evaluating the express lane part of the corridor.

7.0 Public-Private Partnerships and Highway Cost Allocation

PPPs may complicate highway cost allocation somewhat as they introduce a new class of highway owners: private firms. The structure of PPPs varies depending on the agreements between the private sector developer and the public sector transportation agency. Many different contract arrangements are possible regarding size and timing of payments to the public sector agency, percent ownership of the asset, lease terms for leased facilities, performance measures for the facility, responsibilities for facility maintenance, toll enforcement, construction of competing facilities, and many other terms deemed appropriate by the parties to the agreement. The impacts of a particular PPP on the Oregon highway cost allocation (OHCA) process are therefore a function of the specific agreement.

The users of PPP projects usually pay a toll that is collected, controlled, and used by the facility owner to cover operations and maintenance, lease payments if any, and capital charges. Remaining funds become profits. The facility owner usually makes a large up-front payment to the public sector for the rights to build and operate the facility. The new or existing facility becomes part of the road network. It may serve all vehicle types or restrict either light or heavy-duty vehicles. Most PPPs are entered into to raise needed funds by leasing an existing facility or to provide a needed link in the network when traditional funding is not adequate.

How might the existence of privately owned facilities affect the OHCA database? First, we assume that an existing facility is sold (75-year lease) to the private sector to improve the facility, convert to a toll road, and operate at a high level of service. What are the potential impacts on the OHCA process?

- In this case the state is relieved of its obligation to maintain the facility, thus freeing up existing funds for other priorities. These funds may not be expended in the same manner as they would have been if the state continued to operate the facility. In an extreme case they could change facility type (urban-rural, interstate-local) or even modes. An added challenge is uniquely tracking the expenditure of these funds. *How will equity be determined?*
- In many PPPs the private sector provides a large up-front payment for

the facility or pays a periodic lease rate based on performance. The allocation of these funds is a issue that must be resolved. Do they remain transportation funds, or are they available for any purpose the legislature or governor deems worthy and needy? *How will equity be determined?*

- Facility users pay a user fee for the use of the facility that may reflect time of day, vehicle type, emissions, and other factors. They also pay state, federal, and local fees including fuel taxes, VMT fees, weight-distance fees, and registration fees. These revenues to the state are included in the funds to be compared to the allocated costs, but the cost of the PPP facility may not be in the OHCA database. *How will equity be determined?*

Another possibility is that the facility is new and the state did not anticipate maintenance cost responsibilities. The use of any initial or periodic payments must be reconciled with the equity calculations.

There are several options available for future treatment of PPPs in the OHCA. The simplest option would be to treat the facility as part of the state road system, like any other, including the mileage and costs in the database. This would require the initial contract to include provisions for the facility operator to provide the necessary information on costs and revenues. The PPP makes an up-front payment for the rights to collect tolls on the facility over time—a financial arrangement trading the initial payment for future (uncertain) payments. Thus, to avoid double counting, either the purchase price or the tolls should be included in the calculations, but not both. Authorizing legislation can indicate whether revenues will remain dedicated to transportation purposes, which also indicate that revenues would be included in the OHCA.

The other extreme would be to exclude the facility from the OHCA calculations entirely. This would require some calculation of the non-toll fees paid by PPP facility users, such as fuel taxes, that would have to be adjusted for in the OHCA database. These numbers can be reasonably estimated from data on facility VMT, number of users, etc.

To be consistent with the underlying philosophy of highway cost allocation, the appropriate method might be chosen based on on whether private roads are regarded as part of the state's road system or as a private market good outside the scope of interest. Roads that are funded in part by state funds are likely to be considered part of the state road system, however it is unclear whether a road financed entirely with private funds should be included in the state system or be included in the highway cost allocation study. If the road is developed exclusively with private funds and paid for out of toll revenue, then it would seem to be outside of the cost allocation process. In this case, funds are not fungible with other state highway funds and both construction cost and toll revenue would be ignored in highway cost allocation.

8.0 Summary

The use of PPPs to develop transportation projects will increase as they offer an option for state DOTs to meet growing transportation demand with limited funds. Oregon has passed legislation to enable the state to enter into PPPs and the state has begun to investigate projects that might be appropriate for PPPs. Currently, no PPP projects are in place in Oregon and no adjustments to the OHCA procedures are required. However, as such projects are likely to be included in the future, it is appropriate to begin to consider how these projects might affect the process.

Issue Paper 11:

Subdividing Light Vehicle Responsibility

Mark Ford, Mark Ford and Associates, LLC

1.0 Introduction

Oregon cost allocation studies are concerned primarily with the distribution of cost responsibility between light vehicles and heavy vehicles. Light vehicles are defined as those with a gross vehicle weight (GVW) of 10,000 pounds or less. In allocating costs, no distinction is made between various subclasses within this weight group. The 2009 Oregon Highway Cost Allocation Study noted that there is very little difference in cost impact between different size vehicles weighing less than 10,000 pounds There is little difference in road wear due to axle weights, and modern highways are designed with the same lane widths even for vehicles of various widths. Further, on the revenue side, larger light vehicles pay more per mile because of higher fuel consumption. Any small difference in cost responsibility is likely more than compensated by the differences in fees paid.

In contrast to the Oregon methodology, the 1982 federal study considered motorcycles, small autos, large autos, and vans/pickups separately. The 1997 federal study considered autos and motorcycles as one group and vans and pickups as a second group.

Several considerations have recently raised the issue of whether subdivisions of the light vehicle class should be analyzed in Oregon:

- Over time the size of vehicles within the light class has diverged. Up through the 1974 cost responsibility study, the light vehicle was considered to be less than 6,000 pounds, with the vast majority of these vehicles weighing between 2,500 and 4,000 pounds Since that time the maximum limit of the light vehicle has increased to 10,000 pounds and the growth in popularity of SUVs, vans, and large pickup trucks has increased the number of vehicles at the high end of the weight group. The desire for better fuel economy has also increased the number of vehicles at lower weights.
- The introduction of alternative fuel and hybrid vehicles is increasing the divergence in the fuel taxes paid per mile of travel. As fuel economy of vehicles diverges, Oregon and other states are considering collecting mileage fees from light vehicles rather than, or in addition to, fuel taxes. An improved understanding of differences in cost responsibility of the subdivisions of light vehicles would be helpful in determining appropriate rates when mileage fees are implemented.
- Very small passenger vehicles are coming into increasing use. Three-wheel electric vehicles are now seen regularly on city streets. The 2009 legislature authorized a new class of 4-wheeled vehicles referred to as medium-speed electric vehicles (MSEVs). These vehicles have a maximum speed of 35 miles per hour (MPH). Prior to the introduction of MSEVs, “neighborhood” or low-speed electric vehicles (LSEVs) with a maximum speed of 25 MPH were already appearing on local streets. The characteristics and use of these vehicles is considerably different from other types of light vehicles. The cost occasioned by these vehicles may be lower than that of other light vehicles,

although they clearly bear responsibility for the cost of the roads they use.

The methodology of this paper begins by subdividing light vehicles into several groups based on factors that might affect the cost they occasion on the road system and the revenue they contribute. A preliminary estimate is then made of the costs that would be allocated to these subgroups and the revenue they contribute. These preliminary estimates of cost and revenue contributions are then used to estimate the equity ratios of the light vehicle subclasses.

The remainder of this paper is divided into the following sections:

- Section 2.0 describes the subdivisions of the light vehicle classes that could be considered in subsequent cost allocation studies.
- Section 3.0 reviews issues in allocating costs and the likely results of their consideration. This section includes an "experimental" allocation of 2009 light vehicle responsibility to the sub-classes.
- Section 4.0 estimates revenue contributions of the various subdivisions and computes preliminary equity ratios.
- Section 5.0 lists conclusions.

2.0 Defining Light Vehicle Subclasses

Subdivisions of the light vehicle class must be defined in a way that relates to the allocation of costs, with consideration of the fees and taxes that they contribute to the road system. The most comprehensive subdivision of light vehicles for cost allocation purposes was the 1982 Federal Highway Cost Allocation Study. That study considered motorcycles, small automobiles, large automobiles, and pickups/vans separately. The 1997 federal study considered autos and motorcycles as one group and vans and pickups as a second group. Since those studies two additional classes of vehicles are beginning to evolve: LSEVs capable of traveling at speeds up to 25 MPH and MSEVs capable of traveling up to 35 MPH.

The fundamental approach of Oregon's cost allocation process is the cost-occasioned principle. According to this principle each vehicle class should contribute to the cost of providing the road system in proportion to the costs it generates on that system. In theory, costs occasioned could be determined based on multiple factors, including vehicle size and weight, vehicle type (e.g., trucks, buses, passenger cars, SUVs), geographic area (urban/rural), road systems (freeways/ arterials/local), use purpose (commercial/ for hire/private), operational characteristics (including speed and acceleration), or fuel type (diesel, gasoline, electric).

In actuality, some of these considerations will not be relevant until an alternative method of fee collection is implemented that is sensitive to geographic area and road type. Trip purposes would only be relevant if they affected the cost to the public of providing the road system. To the extent that purpose may affect road cost impacts it would largely be reflected in vehicle size, weight, roads used, and time of day. Vehicle speed and acceleration can affect cost allocation of some features such as truck climbing lanes and the passenger car equivalents of vehicles in congested areas. In the past these have been subsumed into the various weight classes.

Each subdivision of light vehicle class contributes road user revenue on a different basis and in different amounts. For instance, electric vehicles currently pay registration fees but no fuel taxes. However, the mode of power makes very little difference to the cost of providing roads and streets and Oregon's approach has been to allocate costs without reference to motive power and, where necessary, to adjust tax collection mechanisms to take account of differences in fuel types.

Based on this brief review of alternatives it appears that at the present time size and weight, and speed to a limited extent, are the only practical factors to consider in evaluating cost responsibility of subdivisions of light vehicles. Power sources of vehicles can be considered in regard to how closely current taxation structures reflect cost responsibility. In the following division of light vehicles, LSEVs and MSEVs are classified and evaluated based on their size and operational characteristics. Note that the classification of these vehicles is the same as would be used if they were conventional gasoline-powered vehicle.

To classify subcategories of vehicles from a cost responsibility point of view, it is important to consider which factors affect the costs. Current cost allocation procedures use the following allocators, which vary by size and weight characteristics of the vehicles:

- Passenger car equivalents (PCE)
- Congested PCE
- Uphill PCE
- Gross weight
- Axle weights and numbers
- Vehicle width (not currently used in the Oregon model, but may be relevant if very small vehicles are compared to large vehicles)

Typical vehicles classed in Oregon as light vehicles range from the larger light vehicle with a maximum gross weight of 10,000 pounds down to different types of low-speed electric vehicles. These vehicles fall into four general groups with two subdivisions.

1. Larger light vehicles include mid-size to large SUVs, vans, and pickups. These vehicles have curb weights from 4,000 to more than 6,500 pounds The larger pickups are capable of carrying cargoes that push their gross weights over 10,000 pounds They range in length from 15.5 to more than 20 feet and have widths from 6.5 to 9 feet. Typical heights of these vehicles are 70 to 80 inches.
2. Traditional passenger cars and small SUVs tend to range from 2,500 to 4,000 pounds, with lengths between 13.5 and 17.5 feet and widths of 5.5 to 6.5 feet. Most are less than 60 inches in height.
3. "City cars" typically weigh less than 2,000 pounds curb weight and have lengths of 10 feet or less and widths of 4.5 to 6 feet. Their heights are similar to passenger cars at 4.5 to 5.5 feet. In terms of safety, fuel, and operational characteristics there are two important subdivisions of city vehicles:
   - Gas-powered vehicles such as the Smart Car meet the same safety standards as other passenger cars and operate at the same speeds.
   - Electric city cars, including LSEVs and MSEVs, are speed limited and have different safety standards from standard passenger cars. From a cost allocation point of view it does not really matter how these vehicles are powered. But because electric vehicles pay no fuel taxes they will have different equity ratio when fees paid are compared to cost responsibility.
4. Motorcycles constitute the fourth group of light vehicles considered in this analysis:.
   - Gas-powered motorcycles are 2-wheeled vehicles designed for one or two riders. These vehicles can range from 100 to over 1,000 pounds, not counting the rider. The smallest of these vehicles may have maximum speeds of 35 to 40 MPH. There are also 3-wheeled gas motorcycles, but they are not considered in this analysis.
   - Electric 3-wheeled motorcycles closely resemble LSEVs and MSEVs in terms of cost allocation factors. However, they lack some of the safety features of those vehicles and in Oregon are registered and operated as motorcycles.

It should be noted that the first two subdivisions may also include electric vehicles. In the case of those two subclasses, engine type would not affect cost allocation.

3.0 Cost Allocation Considerations

3.1 Distribution of VMT by Road System

The distribution of the various subcategories of light vehicles across road systems could have a significant effect on cost allocation. For instance, because LSEVs and MSEVs are not permitted on Interstate Highways, they would bear no responsibility for the cost of those roads. Unfortunately, current traffic classification systems do not separately classify the categories of light vehicles defined in this analysis. If future studies were to consider subdivisions of light vehicles, their distribution among road systems would have to be determined.

Even without a more extensive study, several assumptions about road system use are warranted:

- Passenger cars are likely distributed across all road systems in proportion to the distribution of all light vehicles.
- Larger light vehicles are also spread across all road systems but may tend to use urban roads less and rural roads more than passenger cars. These vehicles probably tend to avoid urban freeways and city streets during congested periods, whereas many of the people traveling on these systems during these times are commuters who likely prefer more economical cars over large SUVs, pickups, and vans. It could be that use of these vehicles is more heavily weighted toward rural areas in general. More research would have to be conducted to confirm this speculation.
- "City cars" are more likely to be found on local urban streets than in other areas. As noted, the subcategories of LSEVs and MSEVs are restricted to roads posted at 35 MPH and 45 MPH, respectively, and would not therefore be found on freeways or rural arterials. It is believed that Smart Car-type vehicles are popular for commuting and would therefore be concentrated on urban roads and during peak periods. It is unclear whether LSEVs and MSEVs would be used for commuting in any different proportion than for general trips throughout the day.
- Motorcycles in general are expected to be spread throughout the road system at all time periods. However, 3-wheeled electric vehicles are specifically designed for short urban trips and are therefore expected to mainly use city streets.

3.2 Light Vehicle Subclasses and Cost Allocators

The Oregon cost allocation study methodology uses a number of cost allocators to assign costs to vehicles and vehicle classes. Impact of the subdivisions of light vehicles in terms of these allocators will be significant in determining their cost responsibility.

3.2.1 Passenger Car Equivalents (PCEs)

Many expenditure categories, including new road surfaces and shoulders and construction of additional bridge capacity, are allocated according to congested PCE in recognition that the expenditures are adding capacity for the vehicles that are currently being delayed on the system. By definition, passenger car congested PCE is 1.0. By contrast, a vehicle with a PCE of 3.0 would displace the equivalent of three passenger cars when entering a congested road and its mileage on the congested road would be multiplied by 3 in calculating its share of PCE-related responsibility.

Several factors affect congested PCE, including the length of the vehicle, its ability to maneuver in traffic, its effect on other vehicles in traffic and its ability to accelerate and maintain sufficient speed to keep up with the traffic flow. These factors vary by vehicle and situation.

Larger light vehicles likely have a PCE and congested PCE greater than 1.0 because of their length, but a significantly lower PCE than large trucks. As a result, they would bear a relatively larger share of costs allocated by PCE than would passenger cars.

City cars that are capable of normal acceleration and normal speeds would have a PCE and a congested PCE slightly below that of a normal passenger car because they are shorter. They may also have an advantage by being narrower and more maneuverable.

The PCE for LSEVs and MSEVs is less clear and could be higher or lower than that for passenger cars. Although these vehicles are shorter and more maneuverable, they are also limited in their ability to maintain traffic flow on roads posted above 25 and 35 MPH, respectively. It was beyond the scope of this analysis to evaluate their accelerating capability, but that could be limited as well. A more thorough evaluation may find that if commonly used they could contribute to congestion more than a normal passenger car and bear a larger responsibility for expenditures intended to reduce congestion.

Motorcycles in general have PCEs less than 1.0 because of their length and their ability to stop side by side, taking up less space at traffic lights. If permitted to travel between lanes in slow-moving or stopped traffic they could have a congested PCE near zero; for safety reasons, Oregon does not permit this. Even without assumptions about using space between lanes, 2-wheeled motorcycles doubtless have a PCE substantially less than 1.0.

The 3-wheeled electric motorcycles have different operating characteristics from other motorcycles that may be closer to LSEVs and MSEVs. Again, more study is required to determine how they affect traffic.

3.2.2 Gross Vehicle Weight and Weight-Based Incremental Method

Gross vehicle weight is an important factor for allocating some types of project expenditures. For example, bridge formulas used in the Oregon study are based on the incremental method of cost allocation. In the incremental method of cost allocation, successive increments of costs are allocated only to those vehicles that are requiring the additional expenditures. In this method heavy vehicles are subdivided into groups so that portion of bridge related expenditures related to weight of vehicles can be allocated to heavier trucks. No subdivisions are made for vehicles weighing less than 10,000 pounds gross weight.

Review of the dimensions and weights of the subclasses created for this evaluation reveals that weight per square foot occupied does not vary widely. For instance, a large SUV with gross weight of 6,500 pounds that is 19 feet long and 7.5 feet wide places a load of approximately 45 pounds per square feet on the bridge. A 2,000 lb. city car that is only 10 feet long and 5 feet wide places a square foot load of 40 pounds per square foot. Furthermore, for large structures the cost of building in strength to hold the dead weight of the structure is often sufficient to accommodate light vehicles before any additional weight loadings are assumed. However, before any final conclusions can be reached, the cost allocation formulas would have to be recalculated with more refined weights.

Responsibility for bridges may also be affected by vehicle width as described below.

3.2.3 Axle Weights

Numbers and weights of axles are the basis of incremental cost allocation and equivalent single axle loads are the basis of allocating much of surface repair costs. However, the heaviest axles of the larger light vehicles evaluated here are still too light to affect construction and maintenance costs of roads constructed to stand up to weather. Therefore, axle weights are not considered in this analysis.

3.2.3 Vehicle Width

In recent years Oregon cost allocation studies have not considered vehicle width because designers determined that highways would be built with the same lane widths even if used only by light vehicles. This conclusion may not hold if the light vehicle class is subdivided to consider new classes of city cars and motorcycles. Lanes of 10 to 12 feet would be unnecessary for LSEVs and MSEVs operating at speeds of 35 MPH and less. Likewise, if motorcycles were treated as a separate class, neither 2-wheeled nor 3-wheeled cycles would require the same lane widths as passenger cars and larger light vehicles. Given that vehicles in these smaller classes typically have widths below 5.5 feet, the basic lane requirement could be 8 or 8.5 feet.

Narrower lane widths would have two important impacts on cost allocation. First, the basic increment of road surface construction and rehabilitation would be substantially smaller. Second, the basic increment of bridge construction and replacement would be smaller because bridge deck for that increment would be narrower. The effect of vehicle width on redistribution of light vehicle costs could be the most substantial factor in reallocating costs.

3.3 An Experimental Reallocation of Light Vehicle Cost Responsibility

To understand how these differences in allocation factors might affect overall cost allocation, a brief experiment was conducted in which 2009 light vehicle allocations were reallocated to the various light vehicle subdivisions. By comparing the reallocation results with assumed distribution of mileage of the subclasses it is possible to estimate a potential range of differences in allocation that could result from subdividing the light vehicle class. Table 1 shows the assumptions that were used in reallocating light vehicle costs. It must be noted that the cost allocation model was not run as a part of this experiment.

In reallocating costs the following procedures and assumptions were used:

Modernization, except pavement and bridges – urban was allocated by congested PCE and rural by mileage.

Preservation, except pavements and bridges – allocated by mileage.

Maintenance, except pavement – allocated by vehicle miles of travel (VMT).

New pavement – allocated incrementally assuming that city cars and motorcycles required a pavement only 67 percent as wide as passenger cars and larger light vehicles. No impact of axle weights is considered. The basic increments of urban pavements were allocated by congested PCE and basic increments of rural pavements by vehicle miles.

Pavement and shoulder reconstruction and rehabilitation – It was assumed that axle weights within the ranges of the light vehicle subdivisions had no impact on pavement deterioration. It was further assumed that city cars and motorcycles shared responsibility for only two thirds of pavement width. The basic increment of urban surfaces and shoulders was allocated by congested PCE, while the

Table 1: Allocation Factors Used in Reallocation Experiment

Vehicle Sub Class	Miles		Percent of Miles	Congested PCE	Lane Width Requirement	Typical Gross Weight (lbs).	Typical Axle Weight (lbs.)
Larger Basic Vehicles	10,723		30%	1.25	100%	6,000	3,000
Passenger Cars	22,161		62%	1.00	100%	3,000	1,500
City Cars - Gasoline	357	urban	1%	1.00	67%	1,500	750
City Cars - Electric	357	urban	1%	1.00	67%	1,500	750
Motorcycles - Electric	357	urban	1%	1.00	67%	1,500	750
Motorcycles - Gasoline	1,787		5%	0.50	67%	750	n.a.
Total	35,743		100%				

basic increment of rural surfaces and shoulder was allocated by VMT.

Pavement maintenance – For pavement maintenance neither axle weight nor roadway width was considered. These costs were allocated by VMT.

Other pavement expenditures – allocated by VMT.

Bridge and interchange construction – allocated incrementally assuming that city cars and motorcycles would require only two thirds the deck width as other light vehicles. The basic increment of urban bridges was allocated by congested PCE, while the basic increment of rural bridges was allocated by vehicle miles. No adjustment was made for gross weight.

Bridge maintenance – allocated by VMT.

Other costs – allocated by VMT.

Prior bonds – reallocated in proportion to all other modernization costs, including new pavements and bridges.

The results of this experimental analysis are shown in Table 2. The first column shows the assumed VMT used in the analysis. The second column shows the distribution of costs that resulted from the analysis. The third column compares the experimental analysis to the distribution of costs that would have occurred if all light vehicles were treated the same way on a per mile basis, as they are today. A percentage of more than 100 percent in the third column indicates that the class has a higher responsibility per mile than the average of all light vehicles. Likewise a result of less than 100 percent indicates a lower than average responsibility. The forth column simply restates the relative responsibilities in terms of percent under or over the average of all light vehicles.

The results show that using these allocation factors, larger light vehicles are probably responsible for 3.7 percent more costs than the average light vehicle under the current allocation process, which combines all vehicles into a single class. Passenger cars are very close to even whereas city cars and motorcycles have estimated responsibilities that are 7.5 percent and 12.9 percent lower than the average. These costs are the result of the longer length of these vehicles, which increases their congested PCE and axle weights, which though much lighter than large trucks still have a greater impact than those of smaller vehicles. The fact that there is not more variation in responsibility by these subdivisions is in large part because many costs allocated to light vehicles in general do not vary with size and are allocated on the basis of VMT.

Table 2: Results of Allocating Light Vehicle Costs Among Sub Groups

Vehicle Sub Class	Percent of VMT	Percent of Reallocated Cost	Ratio of Cost Responsibility to Mileage	Percent over (under) combined class
Larger Basic Vehicles	30.0%	31.1%	103.7%	3.7%
Passenger Cars	62.0%	61.8%	99.6%	-0.4%
City Cars - Gasoline	1.0%	0.9%	92.5%	-7.5%
City Cars - Electric	1.0%	0.9%	92.5%	-7.5%
Motorcycles - Electric (3W)	1.0%	0.9%	92.5%	-7.5%
Motorcycles - Gasoline (2W)	5.0%	4.4%	87.1%	-12.9%
Total	100.0%	100.0%		

4.0 Revenue Attribution and Likely Equity Ratios

Currently light vehicles contribute to the state highway fund through vehicle registration fees and fuel taxes. For any specific vehicle, the total taxes paid to the fund will be a function of the amount of travel, the fuel consumption rate (miles per gallon [MPG]), plus the registration fee. A 2002 study of the Oregon motor vehicle fleet found that vehicles with maximum gross weights under 10,000 pounds had an average fuel consumption of 21.5 MPG. Considering weights of typical vehicles in the subdivisions of the light vehicle class allowed an estimate of the difference in MPG for each subgroup. All light vehicles, including city

Table 3: Annual Fees Paid, by Vehicle Subclass

Vehicle Sub Class	Miles per Year of Travel 6,000	12,000	18,000
Larger Basic Vehicles	$ 123.90	$ 204.80	$ 285.70
Passenger Cars	$ 105.07	$ 167.14	$ 229.21
City Cars - Gasoline	$ 81.92	$ 120.84	$ 159.76
City Cars - Electric	$ 43.00	$ 43.00	$ 43.00
Motorcycles - Electric	$ 21.50	$ 21.50	$ 21.50
Motorcycles - Gasoline	$ 45.49	$ 66.99	$ 88.48
Average - All Basic Vehicles	$ 109.98	$ 176.95	$ 243.93

cars and electric vehicles but excluding motorcycles, pay a registration fee of $43.00 per year.

Larger light vehicle mileage ranges from less than 10 MPG for large older vans and pickups to more than 30 MPG for some SUV hybrids. The fleet average for these vehicles is estimated to be 17.8 MPG.

Mileage of passenger cars ranges from less than 10 MPG for some older high performance vehicles to nearly 50 MPG for some hybrid vehicles. The fleet average is estimated to be 23.2 MPG.

Within the city car subgroup are two types of vehicles—electric and gasoline powered. The most common gasoline vehicle in this category gets an average of 37 MPG.

Motorcycles pay a lower registration fee of $24.00 per year, with electric motorcycles paying $21.50 per year. Fuel consumption rates for gasoline-powered motorcycles range from less than 30 MPG for some of the large older bikes to more than 100 MPG for 50cc scooters. For this analysis the estimated average is estimated average in Oregon is 67 MPG.

Table 4: Equity Ratios at Average Mileage of 12,000 per Year

Vehicle Sub Class	Cost as % of Avg.	Payment % of Avg.	Equity Ratio
Larger Basic Vehicles	103.7%	116%	1.12
Passenger Cars	99.6%	94%	0.95
City Cars - Gasoline	92.5%	68%	0.74
City Cars - Electric	92.5%	24%	0.26
Motorcycles - Electric	92.5%	12%	0.13
Motorcycles - Gasoline	87.1%	38%	0.43
Average - All Basic Vehicles	100.0%	100%	1.00

The following table shows the fees paid by various subclasses of light vehicles based on miles traveled. This table assumes the existing fuel tax rate of $0.24 per gallon and new registration rates that went into effect following passage of HB 2001. Fuel tax rates will rise to $0.30 per gallon on January 1, 2011.

Table 4 estimates equity ratios by comparing the relation of each subclass to the average light vehicle in both cost allocation and revenue attribution. Costs are shown as a per mile percentage of average vehicle costs. This is the same calculation as the last column of Table 2. The second column shows payments by each of the various vehicle subclasses as a percent of average at 12,000 miles per year. These figures are based on the 12,000 mile column of Table 3. The third column shows the ratio of costs as a percent of average to payments as a percent of average. An equity ratio of 1.00 indicates that the share of revenues paid by this vehicle class is equal to the share of cost responsibility share of the vehicle class in the experimental allocation.

It must be noted that if the actual mileages of the subclasses were known, the equity ratios would change, with the equity ratios of those vehicles traveling less than 12,000 miles per year showing an increase. It is unlikely, however, that this would change the fundamental conclusions of the table.

According to this calculation, larger light vehicles are paying more than their cost responsibility while passenger cars are paying slightly less than their responsibility. Other, smaller vehicles have equity ratios substantially below 1.0, indicating they do not cover the costs they occasion on the road system. In the case of electric city cars (LSEVs and MSEVs) this is the result of the fact that they have cost allocations only slightly below passenger cars but do not pay fuel taxes. In the case of 3-wheeled electric motorcycles, these vehicles generate roughly the same costs as electric city cars but pay only motorcycle registrations and no fuel taxes. Gasoline-powered motorcycles have an equity ratio of 0.43 in this experiment. Their cost responsibility is roughly 87 percent of that of the average light vehicles, but because of lower registration fees and high fuel efficiency they pay only 38 percent of the taxes paid by the average passenger vehicle.

5.0 Conclusions

Although the specific conclusions of this paper regarding equity ratios and allocated cost are very preliminary and subject to further research, there are two general conclusions that can still be made:

- The majority of light vehicles, those with registered gross weights less than 10,000 pounds, fall fairly neatly into two classes: passenger cars and larger light vehicles, including light trucks, vans, and SUVs. Although larger light vehicles generate slightly more costs on the road system, they also pay higher taxes because of lower fuel economy. It is unlikely that further analysis would find significant inequities justifying breaking these into separate taxation classes.
- Electric vehicles and very-high-mileage vehicles are likely significantly underpaying their cost responsibility. Even assuming narrower lanes and lower bridge and road costs needed to accommodate these vehicles, it still appears they do not cover the costs they impose on the system. At the present time these vehicles constitute only a small fraction of the fleet. However, more research on cost allocation as it affects these vehicles and more thought to highway tax policy will be important as they become more common.
- To more accurately define the cost responsibility of subclasses of light vehicles there are a number of areas in which future research is necessary:
  - Determination of travel characteristics of subclasses, especially LSEVs and MSEVs, including both total mileage and travel by road system
  - Better understanding of congested PCEs and how they are affected by operational characteristics of light vehicle subclasses
  - Roadway design requirements of city cars and motorcycles, including lane widths
  - Bridge design considerations that would be affected by changes in the basic increment and by deck width.

Appendix C

Meeting Minutes

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of January 4, 2010
10:00 a.m. to 12:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Tim Morgan, Mazen Malik, Doug Anderson, John Oshel, Doug Tindall, Don Negri, Mike McArthur, John Gallup
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Craig Campbell, Bill Morgan, Gabe Cox, Lani Pennington

Welcome, Introductions & Opening Remarks

Tom Potiowsky opened the meeting at 10:00 a.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

Tom reviewed the purpose of the SRT. He emphasized the value that the SRT provides to DAS and the consultant in the development of the Highway Cost Allocation Study. He noted that the group's role is advisory, and that the contractor will determine how to incorporate suggestions. He thanked the SRT members for donating their time to this effort.

Summary of 2009 Results

Carl and John Merriss briefly discussed the 2009 study results. The 2009 study showed that light vehicles were slightly lower than equity. Based on these results the legislature increased overall revenues but did not attempt to adjust intra- or inter-class equity.

Carl noted that a new pavement model was developed after the 2009 study and will be used for the 2011 study.

John distributed a summary of the 2009 study. He noted that a particular area of focus for the 2009 study was a comprehensive documentation of the process and model.

2011 Work Plan

Carl distributed a copy of the work plan for the 2011 study.

The work plan spreads the issue papers over a longer time period than in the 2009 study. The draft papers would be presented between March and June with finalized papers in August.

Carl indicated that the traditional and efficient fee studies would be conducted jointly and that they share much of the same data requirements.

The following issue papers were identified to be studied:

- Treatment of Alternative Fee Paying vehicles
- Data requirements
- Bridge expenditures – primarily for the efficient fee study
- Methodological issues – will be presented at a special meeting in March
- Toll financing – focused on efficient fee and potential new toll mechanisms
- Inclusion of additional vehicle subclasses such as motorcycles, medium and full speed electric vehicles, etc.
- Implications of new revenue instruments, especially related to carbon taxes
- Pavement costs
- Non-pavement wear and tear
- Methods and data for a congestion fee.
- Proper treatment of capital investments that do not increase capacity.
- Studded tire costs
- Proper treatment of un-allocable costs
- Externalities, including freight mobility

The following issue papers that were originally identified in the RFP were determined to have been covered adequately in prior studies or are a low priority:

- Allocation of costs and expenditures at all levels of government
- Equity issues in dimensions other than vehicle weight

It was noted that all issue papers should have conclusions and recommendations to make them more useful.

Next Meeting and Meeting Location

The next SRT meeting will be held on March 1 from 8-12. Carl will lead a discussion of the differences between the efficient fee and traditional cost studies.

The meeting was adjourned at 12:00 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of March 1, 2010
8:00 a.m. to 12:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Tim Morgan, Mazen Malik, Jon Oshel, Don Negri, John Gallup, Doug Tindall, Doug Anderson
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Bill Morgan, Lani Pennington

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 8:10 a.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

Tom explained that the purpose of the meeting was to describe the highway cost allocation process and to discuss the traditional methodology and the efficient fee methodology.

Three typos were noted in the January 4th minutes and the minutes were approved as corrected.

Carl added an additional agenda item – discussion of an issue paper regarding alternate fee paying vehicles.

Discussion of Traditional and Efficient Fee Methodologies

Carl presented a paper that described the traditional and efficient fee approaches to highway cost allocation studies.

There was a discussion on the appropriate frequency of highway cost allocation studies. It may be most appropriate to have a 5-10 year frequency to smooth any swings in revenue impacts. It was noted that the 2 year frequency is in the constitution. Averaging impacts over several studies would help to smooth any revenue impacts. It was also noted that a study should be conducted whenever a major change occurs, such as replacing the weight/ mile tax with a fuel tax.

Carl described the equity ratio concept and noted that the study assumes that the tax structure does not change.

He noted that the efficient fee approach assumes that behavior doesn't change based on the fees calculated by this approach. In real life, the purpose of the efficient fee approach is to induce changes in behavior. Efficient fee calculations serve the purpose of demonstrating whether the current revenue ratios mirror those that would be expected under an efficient fee approach.

It was noted that the equity ratios are currently based on planned expenditures rather than expenditures required to bring the highways up to standard and to maintain them at that level. An efficient fee approach approaches the issue from the perspective of cost, rather than planned expenditures, which may or may not match the allocation based on planned expenditures.

Carl indicated that the majority of pavement costs are allocated based on the national pavement model. Bridges are allocated based on an incremental approach, i.e. the cost associated with a bridge to carry basic vehicles is allocated to all vehicles while the additional cost to serve heavier vehicles is allocated to the heavier classes.

Currently bridge costs are based on a 2002 study. It was noted that height requirements have changed since then. Another significant change is the fish passage requirements. A new bridge study may be warranted.

It was noted that the "other" category of expenditures is the largest. Further detail to break down this category would improve the accuracy of the study; however the impact would depend on whether the allocation basis for the detailed categories varied between categories.

Costs imposed on the roads vary according to whether the roads have been well maintained as well as the composition of the roads. Efficient fee may not accurately represent the costs because the actual current condition of the roads is not accounted for. The study will include an estimate of the cost necessary to maintain the roads if they were currently up to standard.

Carl described the calculation of the congestion fee portion of the efficient fee study. The fee is based on the relationship of speed and overall flow as well as length of delay as a function of volume. The fee is set such that the cost of entering a congested area is equal to the cost imposed by an additional vehicle at that point in time.

Emissions framework will be developed in this study but it is not likely that the necessary data will be available to fully incorporate the impacts. There was discussion regarding whether highway cost externalities should be incorporated in the study and to what extent. Final results will be reported both including and excluding the estimated impacts of emissions.

The study will also address the costs associated with bringing roads from their current condition up to standards and to address costs associated with changes in standards, for example the change in costs associated from increasing the maximum weight limit from 105,000 lbs to 129,000 lbs.

Potential Issue Paper – Alternative Fee Vehicles

Oregon treatment of alternative fee vehicles is unique. An issue paper was proposed to investigate the impacts of the current subsidy adjustment. The paper will look at four options:

1. Full fee paying vehicles plus allocation of subsidy based on VMT (current method)
2. Full fee paying vehicles with a different allocation of the subsidy

3. Only use full fee paying vehicles
4. Use all vehicles

Carl handed out the final list of 10 issue papers.

Next Meeting and Meeting Location

The next meeting will be held on April 12 from 9:30 a.m. to 12:00 p.m. in Conference Room A of the DAS Executive Building.

Tom adjourned the meeting at 12:00 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of April 12, 2010
9:30 a.m. to 12:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Tim Morgan, Mazen Malik, Jon Oshel, Don Negri, John Gallup, Doug Anderson
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Bill Morgan, Lani Pennington

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 9:30 a.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

Tom explained that the purpose of the meeting was to describe the highway cost allocation process and to discuss the traditional methodology and the efficient fee methodology.

Corrections were noted for the March 1, 2010 minutes and the minutes were approved as corrected.

Discussion of Congestion Fee

Carl gave an overview of how a congestion fee would be calculated:

- Profiles would be collected from 140 traffic counters.
- Roads without recorders would be modeled based on similar roads with traffic counters.
    - Extrapolation would be based on annual average usage on HPMS segments.
- Study will use total need for all aspects – congestion, safety, fish, emissions, etc.
    - Carl noted that the characteristics of each are different. For example, no matter how much is spent on safety someone will still have an accident whereas congestion can be solved if enough resources are devoted.
    - Accidents have two aspects – the cost of the accident to those involved and the cost to the system based on the congestion caused by the accident. The congestion fee recovers only the latter.
- PCE used as allocator for congestion based on a Battelle study that varies PCE depending on congestion
- Study would be driven by assumptions due to a general lack of data
    - There was discussion about planning for future data requirements including the use of pilots and temporary metering

- The model's ability to represent non-metered roads can be tested by extrapolating to a metered road and comparing to actual metered data

Once an efficient fee system is in place it is not necessary to allocate highway costs because each person would be paying a fee equal to the costs they impose on the system.

It was suggested that Jim Whitty be invited to present information on the current congestion pricing pilot.

Issue Paper – Alternative Fee Vehicles

Inputs for the paper were drafted by John Skolnick and Mark Ford. John was to propose a different alternative to the Oregon methodology. Mark was to defend the current method. They concluded that it is appropriate to continue to consider the alternative fee vehicles.

Exempt vehicles in other state studies are not explicitly recognized which results in vehicles with each class pick up the costs of exempt vehicles within the class. The authors believe that there is no specific logic to allocating the costs of exempt vehicles solely to vehicles within their weight class. The exemption is based on a general welfare issue. For example school busses serve the population as a whole.

Flat fee vehicles are not the same as other alternative vehicles. It is appropriate to consider flat fee vehicles separately. Some end up paying more than they would under standard fees, some pay less. To the extent that the flat fee vehicles pay an amount that is different than what would be paid under standard fees it is not an intentional difference. The flat fee is intended to reduce paperwork for this class of vehicles.

John Skolnick proposes that the costs and revenues for alternative fee vehicles be removed from the study entirely.

It was noted that the paper should indicate the magnitude of the study.

It was also noted that state construction vehicles should be specifically addressed because they were the original alternative fee vehicles.

Another particular issue may be the hybrid and electric vehicles.

The paper will conclude with a specific recommendation.

Next Meeting and Meeting Location

The next meeting will be held on May 17 from 1:30 p.m. to 4:00 p.m. in Conference Room A of the DAS Executive Building.

Tom adjourned the meeting at 12:00 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of May 17, 2010
1:30 p.m. to 4:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Tim Morgan, Mazen Malik, Jon Oshel, Don Negri, John Gallup, Doug Anderson, Doug Tindall, Doug Benzon (by phone)
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Lani Pennington, Mark Ford, Craig Campbell

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 1:30 p.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

Corrections were noted for the April 12, 2010 minutes and the minutes were approved as corrected.

Discussion of Emissions Fee issue paper

Sarah presented the emissions fee issue paper:

- Toxic versus green house gases are differentiate due to potential different valuation methodology.
- Emissions are determined on a volume per mile basis using MOVES 2010 federal model
  - Resulting emissions are multiplied by the cost per unit volume to determine overall cost.
  - Oregon is currently developing an emissions model as well. ECONorthwest will coordinate with the Oregon developers.
- Emissions are costs imposed by the use of vehicles, but not borne by the user
  - Efficient fee will estimate these costs and assign them to the user.
  - Question was raised about use revenues from a hypothetical fee for non-highway costs.
  - It was noted that the model determines the cost or damage caused by emissions, not revenue that might be collected and is independent of current law. The use of any revenues generated would be determined by the law establishing the collection mechanism.
- Carl noted that there were a variety of methods to estimate the costs of externalities such as impact on human health.
- Per mile estimates by vehicle will be applied to Oregon specific VMT by vehicle class.

- There was discussion about whether it was appropriate to include the costs in the study. It was decided the results should be presented with and without externalities.
- It was noted that there is insufficient data currently to prepare a detailed analysis. The study will note the data requirements to inform the legislature.

Discussion of Basic Vehicle Sub-Class issue paper

Mark Ford presented the basic vehicle sub-class issue paper:

- The question researched for the paper was whether the basic vehicle class should be sub-divided into multiple classes.
  - Small cars are getting smaller
  - Trucks are getting bigger
  - Hybrids and electrics use very little or no gasoline
- Allocators have not been studied for subclasses and impacts are unknown. For example a low-speed electric city car may increase or decrease congestion.
- Gross weight differences are not an issue.
- Vehicle widths differences are significant. Smaller vehicles would not need current standard lane widths.
- General findings are that large basic vehicles cost is about 20% more than currently allocated, passenger cars' cost is about 7% less than currently allocated.
- Equity ratios are approximately 95% for large vehicles, 102% for passenger cars and 15% - 85% for motorcycles and small vehicles.

Discussion of Additional Efficient Fee Components issue paper

Carl presented the additional efficient fee components issue paper which is still under development:

- The purpose is to identify if there are additional categories of externalities that should be included similarly to emissions:
  - Noise
  - Water pollution
  - Aesthetics
  - Fish passage
  - Security
  - ADA
  - Environmental Justice
  - Etc.
- Some of these other categories are weight related, such as replacement of a culvert with a bridge, others are not.
- As with emissions, data is sparse for these aspects
- Question raised "how does the analysis account for the cost that is necessary to bring the system up to standard"?
  - The study develops a hypothetical fee for the incremental cost. The study does not address costs to bring the system up to standard.
  - How does the cost of mitigating fish passage differ from other costs that are reflection of the system being below standard?
  - Distinction may be subjective.
- The paper will be used to help prioritize mitigation efforts for these externalities.

Next Meeting and Meeting Location

Don Negri offered to describe efficient fee pricing theory at the June meeting.

The next meeting will be held on June 28 from 9:30 a.m. to 12:00 p.m. in Conference Room A of the DAS Executive Building.

Tom adjourned the meeting at 3:30 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of June 28, 2010
9:30 a.m. to 12:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Josh Lehner (for Tom Potiowsky), Bob Russell, Tim Morgan (by phone), Mazen Malik, Jon Oshel, Don Negri, Jerri Bohard
Support Staff and Interested Parties
Jamie Drakos (for Brian Hedman), Carl Batten, John Merriss, Sarah Dammen, Lani Pennington, Roger Mingo (by phone)

Welcome, Introductions & Opening Remarks

Josh opened the meeting at 9:30 a.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

The minutes from the May 17, 2010 meeting were approved.

Discussion of New Pavement Model

Roger Mingo described the new pavement model.

- Pavement damage models rewritten from scratch.
- New pavement model based on research by Battelle including Mechanistic Empirical Pavement Design Guide.
    - Previous road tests empirically derived impacts of trucks
    - Mechanistic models were based on pavement engineering
    - The mechanistic empirical approach uses mechanistic theories and calibrates their parameters with empirical research
- The new model will be able to approximate Oregon inputs based on typical Oregon climate zones.
    - Currently Oregon will be approximated by roads in close proximity to states that are directly modeled
    - An Oregon specific analysis could be funded separately
- Concerns were raised that the new model is just a new "black box"
    - Roger indicated that the new model is more transparent than the previous models
    - Pavement costs are a significant portion of highway costs. It was noted that the paper describing the model was difficult for the layman to understand.
    - It was suggested that sensitivity analyses could be run to see how the model reacts and that this would also raise the level of understanding of the SRT members.

- The purpose of the NAPCOM model is to apportion costs between vehicle types. It does not determine the cost itself.
- Studded tires are still not modeled within NAPCOM. Estimates are developed outside the model based on conversations with Oregon pavement engineers.
- Roger will provide further explanations and an overview of the model in the final version of the paper.
- The graphs on page 8 and 9 need to have labels.
- It was noted the present paper is more informative and clearer than previous papers on this topic.
- It was suggested that ODOT be consulted to determine the cost and feasibility of providing data for sensitivity analyses.
- A desire was expressed to have the costs of new pavements, pavement preservation and pavement maintenance separately analyzed. Carl indicated that certain elements such as striping are currently separated out.

Discussion of Efficient Fee Treatment of Pavement Wear and Tear

Carl presented his paper on the application of the NAPCOM proportions to the efficient fee calculations:

- The NAPCOM proportions can be directly used, only the dollar amounts change.
- Assuming roads were correctly designed, built and maintained, average and marginal costs would be identical. If roads were under-designed, built or maintained, marginal cost will be higher than average cost. Conversely, if roads were over designed, built or maintained, marginal cost will be lower than average cost.
- Marginal costs will be based on the methodology in Ken Small's book "Roadwork", published in 1989.
- VMT estimates will use long-run growth rates.
- It was suggested Dave Kavanaugh present his VMT estimates and forecasts when they are developed. His presentation will most likely be at the September SRT meeting.
- Bridge costs will be analyzed separately from the basic pavement issues.

Discussion of Efficient Fee Pricing Theory

Don Negri presented the background for efficient fee pricing theory:

- Don presented the theory graphically. The graphs have been scanned and included separately.
    - Each point on the demand curve represents how much an individual would pay to drive the first mile, the second mile, and so on. At a high cost few miles would be driven; at a low cost many miles would be driven.
    - Each individual also has a cost to drive each mile (fuel, depreciation, maintenance).
    - Each individual will drive the number of miles up to the point where the cost exceeds the value of the next mile
    - Summing all individual demand curves gives the total demand on the roads
    - Likewise, summing each individual's costs gives the total "non-public" cost, i.e. the cost of the individual vehicles only
    - Need to add in public costs (pavement, maintenance, congestion, overhead, emissions)

- Public costs increase as total miles driven increase
- People are willing to pay some price to avoid the impact on the public costs
- Because public costs are not imposed directly on individuals, more miles are driven than would be driven if they were paying incrementally (as they do for fuel, maintenance, etc)
- Efficient fee should be set such that the miles driven are at the point at which the sum of the public cost and private cost curves intersect the sum of the private value (demand) curve.
- Public costs vary with time of day, day of week and location of road.
- The analysis is dynamic, it changes as fees are collected and roads are modified.

Status of Data Collection

Sarah indicated the following data has been received:

- DMV
- Motor carrier registration
- Road use assessment fee
- Loops detector data
- Weigh in motion data
- HPMS data (same submission as previous years), will be supplemented

The following data is still outstanding:

- Flat fee miles and revenues
- Weight-mile tax miles and revenues
- Local road street survey (late July)
- Financial data (late August/early September)

Next Meeting and Meeting Location

The next meeting will be held on August 13 from 1:30 p.m. to 4:00 p.m. in Conference Room A of the DAS Executive Building.

Josh adjourned the meeting at 12:00 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of August 13, 2010
1:30 p.m. to 4:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Josh Lehner (for Tom Potiowsky), Bob Russell, Craig Campbell (for Tim Morgan), Mazen Malik, Jon Oshel, Jerri Bohard, John Gallup
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Lani Pennington, Deborah Dunn, Bill Morgan

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 1:30 p.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

The minutes of the June 28, 2010 meeting were approved with one grammatical edit.

Status of Data Collection

Sarah indicated the following data has been received:
- Weight mile tax
- Flat fee data

These complete the data items typically received prior to the revenue data anticipated in September.

Issue paper – Treatment of Unallocable Costs

Mark Ford presented the treatment of unallocable costs issue paper.

Unallocable costs:
- Costs that are not affected by vehicle use or size, weight or other operating characteristics.
- Currently allocated by VMT or PCE-weighted VMT.
- These costs account for approximately 32% of the total costs allocated in recent studies.
- Possible allocations include those based on demand elasticities to achieve economic efficiency; however, these elasticities vary as much within vehicle classes as between classes.
- Factors to consider in assigning unallocable costs:
    - Does the expenditure benefit users or particular classes of users? If so, the

allocating mechanism should reflect these benefits.
    - Within the classes of benefiting vehicles, are there incremental costs associated with size and weight? If so, the allocating mechanism should reflect these incremental costs.
    - If there are no cost increments associated with the benefiting classes of vehicles, then the allocating mechanism should be based on generally accepted measures of equity.
- There are political and equity issues to consider as well as economic.
- List of potential unallocable costs is not intended to be comprehensive. The full list includes any cost that does not vary by VMT nor adds capacity.
- The paper presents the impact of a potential change in seven categories.
    - The impact is minimal on a dollar basis, with the exception of Administration.
    - Administration category actually includes some costs more appropriately assigned directly.
    - Carl will work with ODOT staff to break out administrative costs in finer detail.
- Changes to the allocation methodology will be contingent on further discussions if additional administrative cost detail can be obtained.

Discussion of Local Agency Expenditures

Mark Ford presented his paper on the trends in local agency expenditures:

- Review of agency trends that might affect allocations now or in the future.
- Conclusion is that no change is needed now.
- More than one-half of local expenditures are with funds that are not generated locally.
- HB 2001 is generating additional highway funds for local agencies.
    - Half of the counties will lose more from the decline in federal timber receipts than they gain from HB 2001.
- There is an increased reliance on special levies.
    - Special levies are typically not fungible with other funding sources.
- Only a few counties generate specific highway and road revenues from local fees (parking, traffic tickets, utility franchise fees, etc).
- Developer-built roads and improvements are not accounted for.
- In past studies, costs that are approximately equal to local special fee revenues are removed from the study.
- Mileage fees, development fees and utility franchise fees may be a growing source of revenues for local agencies.
- A summary of how local agency expenditures affect the highway cost allocation study should be added to the paper.

Discussion of Toll Roads and Public Private Partnerships

Carl presented the toll roads and public private partnerships (3Ps) issue paper:

- Issue is how to treat these for highway cost allocation purposes.
    - One treatment would be to eliminate the costs from the system; however, users are still paying fuel taxes so there is a mismatch between costs and revenues.
    - Another approach would be to estimate and include the revenues from tolls

as well as the costs of the project.
  - The state would need to require the operator to report the cost of the project and the toll revenues collected.
  - In some cases, toll roads are separate from the state. In other cases the roads are leased from the state with lease payments treated as highway revenues.
- The paper is intended to initiate the consideration of toll roads and public private partnerships for future highway cost studies. There is no immediate impact.

Next Meeting and Meeting Location

The next meeting will be held on October 8 from 9:30 a.m. to 12:00 p.m. in the SFMS Conference Room of the DAS Executive Building.

Tom adjourned the meeting at 3:30 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of October 8, 2010
9:30 a.m. to 12:00 p.m.

DAS Executive Building
SFMS Conference Room, First Floor
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky-via phone, Bob Russell, Tim Morgan, Mazen Malik, Jon Oshel, Jerri Bohard, John Gallup, Don Negri
Support Staff and Interested Parties
Brian Hedman, Carl Batten, John Merriss, Sarah Dammen, Lani Pennington, Bill Morgan, Dan Porter, Victor Dodier

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 9:30 a.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

The minutes of the August 13, 2010 meeting were approved with grammatical edits.

VMT – Revenue Forecast

Dan Porter and John Merriss presented the VMT and Revenue Forecasts:

- Revenue forecast modules include:
    - Motor Fuel
    - Motor Carrier
    - DMV
    - Aviation
- Forecast is based on Global Insights National Forecast plus OEA State economic and demographic forecast.
- Margin of error is 2% - 4%.
- It was noted that the DMV and Motor Carrier percentage of total revenues have increased over the previous forecasts.
- Motor Fuels module drivers include:
    - Fuel prices
    - Fuel efficiency
    - Employment
    - Income
- Motor Carrier module drivers include:
    - Construction
    - Manufacturing
    - Paperboard container production

    - Fuel prices
    - Manufacturing employment
- DMV module drivers include:
    - Population
    - Net migration
    - Total non-farm employment
- HCAS uses December of the prior year forecast to match the agency request budget. Dan noted that the transportation revenue forecasts are generally pretty stable absent any legislative change.
- VMT projections are also based on the December 2009 revenue forecast:
    - 1.7% average annual growth in VMT for Light vehicles
    - 3.6% average annual growth for Medium Heavy vehicles
    - 5.5% average annual growth for Heavy vehicles
    - This growth pattern is consistent with a recovering economy.
- Electrics and hybrids may ultimately have an impact on the forecasts, but currently they represent less than 1% of the VMT, so their impact is minimal.
- General shift to smaller vehicles will mean a higher fleet average MPG in future years. Forecast currently relies on Global Insights forecasted fuel economy.
- The VMT projections based on the June forecast are somewhat lower, but the decrease is proportional across all vehicle classes.

Issue Paper – Bridges

Carl presented the treatment of bridge costs under the efficient fee highway cost study.

- Currently the paper is academic in nature and based on theory.
    - Brian Leshko is updating the paper with empirical research.
- Exponential wear is the currently accepted theory, i.e. wear accelerates as the bridge ages.
- Under the efficient fee approach, the need for replacement is driven by heavy vehicles.
    - Analogous to building a replacement cost fee into usage.
    - This cost may be captured in the front loading of bridge replacement costs.
- Carl has asked engineers whether bridges built to different weight capacities have different lives.
    - It was suggested that examples of different bridge specifications based on input from the bridge engineers be included in the paper.
- Brian Leshko plans to have the paper completed by the end of November.

Status of Data Collection

Sarah indicated the following data has been received:

- Weigh-in-motion data
- Automatic Traffic Recorder data
- Highway Performance Monitoring System data
- Cost data
- Motor carrier registrations
- Payment data
- School bus vehicles/mileage
- Tri-Met vehicles/mileage

- Project expenditures
- Additional agency budget data

Still waiting for recommended individual growth rates for VMT portion of model which is then fed to Roger Mingo for pavement cost allocation factors.

Next Meeting and Meeting Location

The next meeting will be held on November 19 from 1:30 p.m. to 4:00 p.m. in Conference Room A of the DAS Executive Building.

Tom adjourned the meeting at 11:45 a.m.

Oregon Highway Cost Allocation Study Review Team Meeting Minutes of November 19, 2010 1:30 p.m. to 4:00 p.m.

DAS Executive Building
Conference Room A
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Tim Morgan, Mazen Malik, Jon Oshel, John Merriss for Jerri Bohard, Don Negri
Support Staff and Interested Parties
Brian Hedman, Carl Batten, Sarah Dammen, Lani Pennington, Doug Parrow, Craig Campbell

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 1:40 p.m. and welcomed the Study Review Team (SRT) members, support staff and other interested parties. Participants introduced themselves.

The minutes of the October 8, 2010 meeting were approved with changes.

Weigh-in-Motion Analysis

Carl presented the results of the analysis of the weigh-in-motion data:

- Measures weight of each axle and distance between axles for all trucks passing station
- Trucks equipped with transponders can be matched to weight-mile tax data to determine their declared weight.
- Two million records collected compared with about 71,000 for special weighings.
    - Most special weighings are on rural primary and secondary highways off the interstates.
- Empty trucks are not weighed during normal weighings.
- Declared weight collected from weight-mile tax records.
    - For each declared weight, determined distribution of operating weights.
    - Average weight of trucks declared at 80,000 pounds was 61,000 pounds in the special weighings data compared with 55,000 pounds in the weigh-in-motion data, indicating that on average trucks are typically partially loaded or fully loaded but weigh less than the declared weight.
- Carl is working on merging the special weighings and weigh-in-motion data.
- Pavement impacts are based on the distribution of actual operating weights rather than declared weights.

Estimating Congestion Fees

Carl presented a methodology for estimating the appropriate congestion fee.

- The methodology approximates efficient fee revenue given the limited data currently available.
- Used automatic traffic recorder data from a limited number of locations plus the Highway Performance Monitoring System database that describes the characteristics of 30,000 road segments in Oregon.
- Developed a model to describe distribution traffic patterns on each segment at each hour of the year.
- First step is to develop congestion fees for each segment in each hour. Most will be zero.
- Second step is to apply that fee using an expected distribution of cars and trucks on the segment at different times of the day.
- Results could be used to inform policy decisions regarding implementation of congestion pricing.
- More detailed analysis would be required to identify and implement an actual congestion pricing mechanism.

Status of Data Collection

Sarah indicated the following data has been received:

- Project expenditure data
    - $1.23 billion project costs in the next biennium.
    - Several projects involve raising overpasses; therefore there is a need to determine whether raising the overpasses is the primary cost of the project and whether the HCAS should include a category for raising overpasses assigned to large vehicles.
    - Project work-type categorization not yet finalized.
- Non-project expenditure data – other highway division
    - 67% is Special Programs (Central, Regional, Tech Services Construction support)
    - 11% is bridge partner oversight
    - 11% is local government support
    - 8% is traffic operations
    - 2% is rest area improvements and access management
- Non-project expenditure data – other ODOT
    - Debt service for highway fund, which is set aside
    - Rail crossing protection fund
    - Rail crossing work will be treated as pavement rehabilitation
- VMT data collection
    - All data has been received from ODOT. Waiting for FHWA Highway Statistics, which should be available for the final model run.

Next Meeting and Meeting Location

The next meeting will be held on December 17 from 1:30 p.m. to 4:00 p.m. in Conference Room B of the DAS Executive Building to discuss the peer review comments on the issue papers and some outstanding issues. Preliminary results are expected to be distributed by January 1.

A second meeting was scheduled for January 14 from 1:30 p.m. to 4:00 p.m. in Conference Room B of the DAS Executive Building to discuss the final results for both studies.

Tom adjourned the meeting at 3:35 p.m.

Oregon Highway Cost Allocation Study Review Team Meeting Minutes of December 17, 2010 1:30 p.m. to 4:00 p.m.

DAS Executive Building
Conference Room B
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky, Bob Russell, Mazen Malik, Jon Oshel, Jerri Bohard, Don Negri, Craig Campbell (for Tim Morgan) by phone
Support Staff and Interested Parties
Brian Hedman, Carl Batten, Sarah Dammen, John Merriss, Lani Pennington, Bill Morgan, Doug Parrow, Bert Hartman

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 1:35 p.m. and welcomed the Study Review Team (SRT) members and support staff. Participants introduced themselves.

The minutes of the November 19, 2010 meeting were approved with changes.

Issue Paper Peer Review

Carl presented Tony Rufolo's peer review comments on the issue papers:

- Tony expressed some serious reservations about the use of the efficient fee model for cost allocation, particularly with respect to congestion.
- Marginal cost times number of users will not equal total cost.
- The peer review comments and ECONorthwest's response will be incorporated in the final issue papers.

Further discussion among those present included the following points:

- If congestion fees were actually charged, volumes on congested facilities would drop and the actual fee level would be lower than the fees calculated from existing traffic counts.
- It was recognized the data does not yet exist to accurately measure marginal costs, nor is there a mechanism in place to charge an efficient fee; however, the study is intended to begin the discussion to move in that direction.
- Marginal cost pricing is not intended to relieve congestion entirely and even with such pricing in place, there will typically still remain some level of congestion. However, such pricing would allow individual users to choose to pay a higher cost to travel during congested times or pay a lesser cost to travel at uncongested times. In the long run, the revenue collected will fund additional capacity.
- Efficient fees need to vary with the actual current level of congestion in order to be efficient. California's I-680 tolls change every 3 minutes according to congestion.

Outstanding Issues

Alternative fee vehicles

- Alternative fee vehicles include: School buses, government vehicles, transit vehicles, farm vehicles, tow trucks, non-profits, etc.
- Flat fees are intended to be a simpler alternative to the weight-mile tax and will be treated in the same manner as the weight-mile tax.
- Detail of alternative-fee-paying vehicles and the subsidies they receive will be included in the final report to allow for full review.
- The report will also include a more explicit and detailed discussion of the subsidy adjustment and of the equity ratios both with and without the adjustment.

Bridge vertical clearance

- This is the first study that split out the vertical clearance projects and assigned costs directly to heavy vehicles.
- Bert Hartman provided additional information on the vertical clearance projects.
- Individual projects will be analyzed to determine the extent to which vertical clearance beyond the standard contributed to project costs.

Preliminary Results

Carl indicated that preliminary results are under development:

- Pavement factors were received December 14th and are under review
    - Outside of the range of weights where most trucks operate, raw factors do not change smoothly across weight classes.
    - The method Roger Mingo used to smooth the curves resulted in much higher factors for some of the most popular weight classes.
    - Carl proposes to use the raw factors where they are already smooth and then extrapolate the curve outside that range.
- The Traditional HCAS results should be ready by about January 1, 2011.
- The Efficient Fee Study results will be available by about January 14, 2011.
- By statute, a letter stating that the final results are completed and ready for presentation is due to the legislative leadership by January 31, 2011.

Next Meeting and Meeting Location

The next meeting will be held on January 14 from 1:30 p.m. to 4:00 p.m. in Conference Room B of the DAS Executive Building to discuss the final results. The SRT will also discuss how to present the Efficient Fee Study results to the legislature and will make a recommendation on how to proceed next biennium – i.e., whether to perform a second Efficient Fee Study or to conduct an analysis of how the results of this biennium's study can best be used to inform and support ongoing and future congestion pricing implementation efforts in the state, or both.

Tom adjourned the meeting at 3:35 p.m.

Oregon Highway Cost Allocation Study Review Team
Meeting Minutes of January 14, 2011
1:45 p.m. to 4:00 p.m.

DAS Executive Building
Conference Room B
155 Cottage Street N.E.
Salem, Oregon 97301-3966

Attendees: Study Review Team Members
Tom Potiowsky (by phone), Bob Russell, Mazen Malik, Jon Oshel, Jerri Bohard, Don Negri, Tim Morgan
Support Staff and Interested Parties
Brian Hedman, Carl Batten (by phone), Sarah Dammen (by phone), Lani Pennington, John Merriss, Bill Morgan, Doug Parrow, Craig Campbell, Victor Dodier

Welcome, Introductions & Opening Remarks

Tom opened the meeting at 1:45 p.m. and welcomed the Study Review Team (SRT) members, support staff and other interested parties. Participants introduced themselves.

The minutes of the December 17, 2010 meeting were approved with changes.

Traditional Study Draft Results

Carl presented the traditional study draft results:

- The traditional model yields results similar to those of two years ago
- Subsidy amounts increased
  - HB 2001 increased the tax rates proportionally, which increased the dollar amount of subsidy for each subsidized vehicle.
- Subsidized vehicle VMT decreased
  - Flat fee vehicles are no longer considered subsidized and in fact paid more under flat fees than they would have paid in weight-mile taxes in 2009.
  - In 2009, log trucks paid more under flat fees than they would have under the weight-mile tax; in prior studies they had paid less.
  - If flat fee vehicles had been considered to be subsidized, the total subsidy amount would have been lower.
- Differences in heavy vehicle weight classes
  - The differences between the 2009 Study and 2011 Study vary by weight class.
  - These differences are driven by the use of the new pavement factors.
  - The weigh-in-motion data indicates that the 78,001-80,000 pound weight class on average operates even farther below their declared weight than the special weighings data indicates.
  - Vehicles operated at weights above 105,500 pounds are assumed to weigh what their permit indicates. It was noted, however, that even the 105,500+ pound vehicles are typically operated a little bit under their permitted weight

    - in order to avoid penalties, and that they revert to their usual declared weight when traveling empty.
- The SRT discussed whether the results should be presented under both the previous (old) pavement factor model and the new pavement factor model
    - The new model incorporates Oregon-specific weigh-in-motion data to produce more accurate factors.
    - The new factors embody better representations of pavement distresses and better data on pavement wear.
    - It was also noted that presenting multiple sets of results may create confusion.
    - There was concern that the new factors may contain calculation errors or inappropriate extrapolation techniques, as they have gone through several revisions with significant changes each time.
    - Because of this concern, it was agreed the results using the old factors should be the primary results presented in the report and that the results generated using the new factors should be included in the body of the report for comparison.[1]
- The overall results show approximate parity between the major vehicle classes of light vehicles and heavy vehicles as a whole
    - The inequity between light and heavy vehicles is considered within the margin of error of the study, regardless of which pavement factors are used.
    - Inequities within the heavy vehicle classes may warrant rate changes, especially for Road Use Assessment Fees.

Efficient Fee Study Draft Results

Carl presented the Efficient Fee Study draft results:

- The efficient fee model results are consistent with those of the traditional model. This is a change from the last time both models were generated.
    - The previous, 2001 Study demonstration analysis did not include an emissions fee or common costs.
    - The current Efficient Fee Study includes more detail and the method used to allocate pavement costs is different.
    - It was suggested the report should emphasize that consistency between the traditional and efficient fee results does not imply that implementation of efficient fees is unwarranted.
    - Efficient fees would engender more efficient use of highways.
    - Efficient fees would lead to more efficient investment in highways and in congestion relief.
    - Implementation of efficient fees would require finding a way to charge a congestion fee.
- The efficient fee report will describe the road map towards implementation
    - Data requirements
    - Pricing mechanisms
    - Technology
    - Next steps

[1] Subsequent to the meeting, the model's author, Roger Mingo, thoroughly reviewed the derivation of the new pavement factors and concluded that they were accurate and stable. The study authors decided to base the primary results on the use of the new factors and report the results of using the old factors in the discussion of pavement responsibility within the body of the report. The base case in the report will use the new factors.

Final Report

The finalization and presentation of the study reports was discussed:

- Two reports will be developed, one for the traditional study and one for the Efficient Fee Study.
- The oral presentation will walk the committee through the road map towards implementation of efficient fees.
- By January 31, 2011, Tom will send the legislative revenue committees the statutorily-mandated letter stating that the studies are completed and ready for presentation to the appropriate committees of the 2011 Legislature.

Next Meeting and Meeting Location

ECONorthwest will present the results of the studies to the revenue committees at their invitation. Tom will notify and invite the SRT members to attend the presentation(s).

Tom adjourned the meeting at 3:55 p.m.

Appendix D

Oregon Highway Cost Allocation Study Model User Guide

The 2011 Oregon Highway Cost Allocation Study (HCAS) User Guide describes the steps required to update and run the 2011 version of the Oregon HCAS Model. A user should be able to modify the model assumptions and update the input data and then recalculate the model with the information in this user guide, along with instructions in the model tabs. The HCAS Model User Guide is organized as follows:

Section 1 provides a general overview of the HCAS model and describes the model workbook structure.

Section 2 lists the computer system requirements and software necessary to run the model. This section also describes how to copy the HCAS Model folder from the distribution CD to the local computer and lists the contents of the HCAS Model folder.

Section 3 describes the data sets and any data pre-processing required to update the HCAS model.

Section 4 describes the input text files, model workbook tabs, and output text files. Each input file is described in terms of the file contents and the data required to update the input text file. The tab-by-tab explanation of the model displays a screen shot of the model tab, and then describes the contents of the worksheet, how the data on the tab are used in the model, and the process for updating the data and other user-specified assumptions.

In Section 5, the user is guided through the steps to recalculate the model results and audit the model calculations using the Audit tab. This section also contains tips for troubleshooting errors from recalculating the model.

Section 6 is a user guide for an alternative rate analysis using the HCAS model. In this section the various revenue instruments of the model are described, along with how alternative rates for each instrument will affect the HCAS model results. The *Alt Rates* tab and Alt Rate output tabs are explained in the same tab-by-tab fashion as the other workbook tabs in Section 4. Three case studies provide step-by-step examples of how to conduct an alternative rates analysis for three different revenue instruments.

Section 1: HCAS Model Overview

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 share of costs and then the user class share of revenues to calculate equity ratios for each user class. Equity ratios close to 1.0 indicate that the vehicle class is paying its share of costs. An equity ratio less than one indicates the vehicle class is paying less than its share of costs, and an equity ratio greater than one indicates the vehicle class is paying more than its share of costs.

The HCAS model, an Excel workbook, is the model user interface for updating data and assumptions used in the model calculations and viewing the output from recalculating the model. The HCAS Model folder contains the HCAS Model workbook and a series of other input text files and supplementary workbooks and the HCAS Module code file. The majority of the model assumptions and data inputs are located in the main HCAS Model user interface. Some data processing and calculations must be performed in either the supplemental workbooks or using database software on the raw data files to produce summarized data tables, which are then pasted into the HCAS Model workbook.

The HCAS Model workbook tabs are oriented from left to right, with the main control tab at the far left, followed by the tabs for the input for the VMT calculations, input for the costs to allocate, revenue input, intermediate output, auditing, summary results, and report tables. The model tabs are colored to indicate specific characteristic: contains data or assumptions that can be changed by the user (yellow); alternative rate analysis user input (lavender); intermediate output or tables (light blue); final results (dark blue); and alternative rate analysis results (dark purple).

To update and run the model, the user edits the model data and parameters as needed and clicks a "Recalculate" button to run the model program. Recalculating the model will call up the HCAS Module program code, which will read in the data from the HCAS Model workbook and the input text files. Using this data, the HCAS program will perform the VMT, cost allocation, revenue attribution, and alternative rates revenue attribution calculations. The HCAS module will then generate a set of output text files in the HCAS Model folder and populate the output in the Model output tabs with the new results.

The instructions and content provided in this user guide are best followed in the order given. Steps where no modifications are needed can be skipped.

Section 2: Initial Set-Up

This section describes the computer system and software requirements to update and run the HCAS model, how to copy the HCAS Model folder from the HCAS distribution CD, and the contents of the HCAS Model folder.

System Requirements and Software, Settings

The HCAS model can be updated and run using standard computer software and available open-source programming software.

System Requirements To run the HCAS model, the user must open the model in Excel 2003 on a computer with a Windows Operating System.

Excel The HCAS model is an Excel workbook that can be run using Microsoft Office Excel 2003. The Excel security options must be set to enable macros.

Python Python is an open-source, object-oriented programming language. The user must download and install the (free) Python software maintained by the Python Software Foundation.[1]

Text Editor A text editor or Excel can be used to view the input and output 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 SQL programming language.

Copy the HCAS Model Folder From the Distribution CD

Insert the HCAS distribution CD into the computer CD disk drive. Open the My Computer window to view the HCAS distribution CD contents. Click and copy

[1] Python can be downloaded from: http://www.python.org/download. The Python Software Foundation website also contains documentation and other related material. The user should consult the Python documentation for additional information on how to install the program and open the Python editor.

the HCAS Model folder (and all of the folder contents) to the local computer.

Contents of the Model Folder

There are three types of files in the HCAS Model folder: Excel files, text files, and a Python file. The HCAS Model user interface is an Excel workbook. The HCASModule.py is a Python file containing the model code that performs the model calculations. In addition to the input and output data in the HCAS Model Excel workbook, the HCAS Module reads in a set of input data files in ".txt" (text) format and will produce output text files. Also included in the HCAS Model folder are supplemental Excel workbooks containing data and calculations performed outside of the Excel model workbook. Table 1 lists the files in the HCAS Model folder on the distribution CD.

Section 3: HCAS Model Data and Pre-processing of Data for Model

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 Highway Cost Allocation Study. For each data set, the data files, source for the data, and any pre-processing of the data outside of the model is described. The SQL code corresponding to the pre-processing of the data for the 2011 HCAS can be found in Appendix F.

Special Weighings Data

Source: ODOT

Special weighings studies are data collected at weigh stations on special days when every truck is weighed. Normally, empty trucks do not need to be weighed. The special weighings data have accumulated from prior studies plus additional studies are completed each year.

Table 1: Files in the HCAS Model Folder

File Name	File Type	File Use
HCAS Model	Excel	Model user interface
Base VMT	Excel	Supplemental Excel workbook
PE and ROW	Excel	Supplemental Excel workbook
HCASModule	Python	Python model code
AxleShares	Text	Input text file
BasicSharePeak	Text	Input text file
Bonds2003-2005	Text	Input text file
Bonds2005-2007	Text	Input text file
Bonds2007-2009	Text	Input text file
declared_pave_factors	Text	Input text file
DeclaredOperating	Text	Input text file
DeclaredRegistered	Text	Input text file
paveFactors	Text	Input text file
PCEFactors	Text	Input text file
SeedData	Text	Input text file
SimpleFactors	Text	Input text file
allocatedCosts_bond	Text	Output text file
allocatedCosts_federal	Text	Output text file
allocatedCosts_local-federal	Text	Output text file
allocatedCosts_local-other	Text	Output text file
allocatedCosts_local-state	Text	Output text file
allocatedCosts_other	Text	Output text file
allocatedCosts_state	Text	Output text file
Bonds2009-2011	Text	Output text file
flat_fee_report	Text	Output text file
missing_pavement_factors	Text	Output text file
VMTMaster	Text	Output text file
SubsidiesbyVehClass	Text	Output text file

Weigh-In-Motion Data

Source: Portland State University/ODOT

Special weighings rarely take place at freeway weighing stations because of the volume of trucks passing through. Weigh-in-motion (WIM) sensors, however, do weigh every truck passing over multiple points on Oregon's freeway system, as well as at other, non-freeway locations. WIM data provide the study with a more-accurate description of the distribution of operating weights.

Pre-processing of Special Weighings Data

Some additional columns are added for the new special weighings data, calculated from the columns in the original data and appended to data from prior special weighings. The WIM data are then appended to the special weighings data, with the two data sources given weight in proportion to the distribution of VMT on functional classes where the weighing data were collected. From the weighings data, we calculate distributions of operating weight for each declared weight and distributions of vehicle configurations for each operating weight. The processed weighings data are used to create the table of the declared weight to operating weight for the *DeclaredOperating* input text file.

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 been reduced, but the data are still extremely useful in highway cost allocation and in developing pavement factors.

Processing of HPMS Data

The entire HPMS data set is an input file for the NAPCAS model. It uses fields that describe pavement characteristics, base, soil type, and climate zone. 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 (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).

To perform the data tabulation of the HPMS data for the *VMT by FC* tab, divide the HPMS section AADT by the section length (after converting the section length from kilometers to miles) to calculate the section VMT. Because HPMS is a sample, each section VMT is expanded by the section weight to estimate the VMT by functional class and ownership statewide. 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.

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* tab in the Base VMT workbook. 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 the base year *Highway 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 HCAS Model and Base VMT workbook tabs where indicated. No pre-processing of this data is required.

GSA *Federal Fleet Report* Data

Source: U.S. General Services Administration, www.gsa.gov/vehiclepolicy

The *Federal Fleet Report* is an annual publication produced by the U.S. General Services Administration (GSA). The *Federal 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 Base VMT workbook as part of the federal vehicle class VMT calculations. 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* tab in the Base VMT workbook lists the tables and rows from the *Federal Fleet Report* that should be pasted into the yellow-shaded cells on the tab. No pre-processing of this data is required.

Transit VMT Data

Source: Tri-Met, Lane Transit District, Salem-Keizer Charriots Transit District

Update the transit bus VMT on the *Transit* tab in the Base VMT workbook with VMT information from the three largest transit agencies in Oregon: Tri-Met, Lane Transit District, and Salem Keizer Charriots. 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 *Transit* tab.

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 to the left of the yellow-shaded *Year* cells.

The base year VMT from the ODOT forecast are also pasted into the *Intermediate Base VMT* tab in the Base VMT workbook for the control total VMT for the light and medium-heavy vehicle classes.

VMT Growth Rates for Heavy Vehicle Classes: Adjust the individual (2,000-pound increment) VMT growth rates for the heavy vehicles (26,001 pounds and up) such that the total heavy vehicle VMT growth rate matches the group VMT growth rate from the ODOT forecast while allowing for variation across weight classes within the heavy vehicles. Small modifications in the growth rates for the groups from 78,001 and 104,001 pounds will have the greatest impact on the total heavy vehicle group VMT growth rate because most heavy vehicle VMT are in these two weight classes. The heavy vehicle class growth rates should not be adjusted until the Base VMT workbook has been completely updated and the HCAS Model workbook link to the Base VMT workbook data has been updated because the group growth rate will depend on the VMT for each individual weight class.

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.[2]

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[2] 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 model. 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, 14,001...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 2000, truncate or round to the decimal point, then multiply by 2000 and add one. Or Trun((Weight-1)/2000)*2000 + 1 in SQL or Round((Weight-1)/2000,0)*2000+1 in Excel.

Axle class is assigned for weight classes 80,001 pounds and up. The HCAS axle class is either a zero, five, six, seven, eight or nine (or more). If the weight class is under 80,001 then 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.

Motor Carrier Registrations Data

Source: Motor Carrier Transportation Division, ODOT

The Motor Carrier Registrations data are used to develop distributions of registered weights by declared weights for the declaredRegistered input text file. For each declared weight category, the declaredRegistered input 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 pre-processed using SQL in PostgreSQL. The share of vehicle registrations for the distribution of registered weights for each declared weight is calculated from the count of registrations. The final processed table for the declaredRegistered input file contains the declared weight, the registered weight, and the share of registrations at that declared weight.

Flat Fee Collections Reports

Source: Motor Carrier Transportation Division, ODOT

The Flat Fee Report data are used to calculate the Flat Fee VMT for the Base VMT workbook and to estimate VMT per month and axle shares for the *Revenue* tab in the HCAS model.

Pre-processing of the Flat Fee Collections Reports

The Flat Fee Collections Reports are processed in an Excel workbook or using SQL queries, depending on how the Flat Fee Report data are delivered. The processed flat fee data are then pasted into the yellow-shaded cells on the *FlatFee* tab of the Base VMT workbook and into the *Revenues* tab in the HCAS Model workbook.

A summary table of the monthly miles and count of the monthly reports from the *Flat Fee Reports* tab should be created using a series of pivot tables, or the user may choose to export the Flat Fee Reports data and create the summary tables using an alternative software program. The pivot table rows are commodity (comm), 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 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 *FlatFee* tab in the Base VMT workbook, the miles reported in the Flat Fee Reports are summed for each commodity and axle class and then the number of non-zero records and total number of records are counted. These fields become columns A through E in the *FlatFee* tab in the Base VMT workbook.

For the *Revenues* tab in the HCAS Model workbook, create a pivot table or summary table results using the Flat Fee 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.

For the 2009 HCAS, SQL queries and a Supplemental Flat Fee workbook were used to pre-process the flat fee data. See the 2009 HCAS User Guide for procedures used in that study.

WMT Collections

Source: Motor Carrier Transportation Division, ODOT

The WMT Collections (or Payments) Reports are pre-processed and used in the Base VMT workbook to determine the VMT for the various WMT vehicle classes.

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. The SQL code for the pre-processing of the WMT data for the 2011 HCAS is provided in Appendix F. The SQL code assigns the records to a weight class and axle class using the HCAS weight class and axle classes, and sums the miles traveled from the WMT Collections Report for each weight and axle class. This summary table is then pasted into the *WMT* tab in the Base VMT workbook.

Road Use Assessment Fee Data

Source: Motor Carrier Transportation Division, ODOT

The road use assessment fee (RUAF) data are the records from the vehicles paying the RUAF at weight class 96,001 pounds and above. Each RUAF record contains an ID number, issue date, axles, weight, miles, and tax. The RUAF data are used to determine the VMT by RUAF vehicles by weight and axle class in the Base VMT workbook.

The RUAF data do not require any pre-processing. Paste the RUAF data directly into the yellow-shaded cells on the *RUAF* tab in the Base VMT workbook. Make sure the weight class and axle class formulas assign a valid weight class and axle class to all of the RUAF records (columns G and H in the *RUAF* tab).

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.

The processing of local government data has evolved significantly in each of the last three studies. For the 2009 Study, the local cost approach and calculations have been formalized and incorporated into the model in the *Local Costs* tab. The same calculations and *Local Costs* tab was used in the 2011 Study. Paste the LRSS data into the *Local Costs* tab and the raw data on base year expenditures to the 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 are pasted into the *Non-Project Costs* tab; no pre-processing is required.

Project Expenditure Data

Source: Various analysts within 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. The project expenditures data are requested when the Agency Request Budget data become available so that the project data are consistent with the budget, around the end of August or early September.

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 expenditures 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 Project Control System
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 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 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.

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[3] 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 2011 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. 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 using the format shown in Table 2.

Table 2 displays an example of the *Project Costs* tab entries for a project that has two funding sources (state and federal) and three work types (11, 21, and 22). "Dollars" is produced by multiplying the total project expenditures in the biennium by the fund source share and work source share. Key number is included for project identification; the key number is not read into the model.

Table 2: Example of a Project With Multiple Work Types and Funding Sources Entered in the *Project Costs* Tab

Funding	Work Type	Functional Class	Bridge Type	Dollars	Key Number
state	11	0	0	1,194,517	15740
state	22	0	0	95,018	15740
state	21	0	0	67,870	15740
federal	11	0	0	10,597,355	15740
federal	22	0	0	842,971	15740
federal	21	0	0	602,122	15740

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 the Revenue Forecast worksheet are pasted into the yellow-shaded cells on the *Rev Forecast* tab in the HCAS workbook; no pre-processing of the data is required. Gross revenue amount by revenue source is linked to the appropriate revenue control total on the *Revenues* tab.

Current-Law Tax Rates and Fee Schedules

Source: Oregon Revised Statues, 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. In particular, the WMT Schedule A and B tables can be found at the MCTD website, where the

[3] 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.

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.

Estimated Average Basic-Vehicle Miles per Gallon

Source: Financial and Economics Analysis Unit, Financial Service Branch, ODOT

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* tab in the model. 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* tab should be generally consistent with the assumptions made by ODOT.

DMV Vehicle Registrations

Source: Department of Motor Vehicles, Request made 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 2011 HCAS, ODOT Financial Services was granted permission to obtain de-identified registration records from DMV.

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. The SQL code used to process the DMV data for the 2011 HCAS can be found in Appendix F.

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 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, E-Plate, and School Buses.

Motor home registrations data do not necessarily include vehicle weight, so registrations are tabulated by vehicle length and assigned a HCAS weight class using vehicle length. The summary table is pasted into the *MotorHomes* tab in the Base VMT workbook and has the following columns: motor home plate indicator (HC), vehicle length, and sum of registrations (by vehicle length).

For the main DMV summary table, weight class is assigned to each registration record by converting the registered vehicle weight to the standard HCAS weight class. A fuel-type variable is also created from the DMV fuel variable to identify whether the vehicle is gasoline powered or non-gasoline powered (gasoline-powered vehicles corresponded with fuel codes 1 or 5 in the 2009 DMV registrations data; fuel type 6 was excluded for the registrations data).

The license plate string is used to identify the vehicle tax classes using the plate vehicle class designations. Table 3 lists the plate identifiers for the vehicle tax classes included in the summary DMV table created for the *DMV* tab in the Base VMT workbook.

Table 3: HCAS Vehicle Classes by DMV Plate Identifier

Plate Identifier	Vehicle Class
B	Bus
CH	Charitable/non-profit
E	Exempt (E-Plate)
F	Farm
HF	Heavy fixed-load (e.g., backhoes)
HS	Heavy trailer (over 8,000 pounds)
PF	Permanent fleet
SC	School bus
TW	Tow truck
T	Truck

Pavement Factors

Source: RD Mingo & Associates

RD Mingo and Associates produce Oregon-specific pavement factors using the Oregon HPMS submittal data in the new 2010 National Pavement Costs Model (NAPCOM). The pavement factors are used to update the *PavementFactors* text file and the pavement allocators on the *Policy* tab. Minimal processing of the pavement factors data may be necessary to get the pavement factors into the correct format for the *PavementFactors* input text file.

Section 4: HCAS Model, Input Files, and Output Files

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. See Appendix E for more information on the input and output text files.

Bonds2003-2005.txt
Bonds2005-2007.txt
Bonds2007-2009.txt
Bonds2009-2011.txt

These files contains the prior allocated bonds from the 2003, 2005, 2007, and 2009 studies, respectively. 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 and the share of vehicles within each operating weight created from the special weighings data. The DeclaredOperating 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 and the share of vehicles within each registered weight created from the Motor Carrier Registrations data. The DeclaredRegistered data are used to attribute registration and title fee revenues.

paveFactors.txt

This file 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 data in the NAPCOM model.

PCEFactors.txt

The *PCEFactors* file contains the passenger-car equivalents (by weight class and number of axles) on regular, uphill, and congested roadways. This file is not updated.

SeedData.txt

The *SeedData* file contains VMT by weight class, functional class, ownership, and number of axles. (This file essentially contains proportions that guide the model as it fits data for the VMT master table.) This file is not updated.

SimpleFactors.txt

This text 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.

Supplemental Excel Workbooks

Two supplemental Excel workbooks are included in the HCAS Model folder for the processing of input data. Each of these workbooks should be updated; the specified output from these workbooks is either pasted into the HCAS Model workbook or, in the case of the Base VMT workbook, the supplemental workbook is linked to the HCAS model. As in the HCAS Model workbook, the majority of the required calculations and data tables are automatically updated when the yellow-shaded input cells are modified.

The supplemental workbooks used in the 2011 HCAS are the Base VMT workbook, which is linked to the *Base VMT* tab in the model, and the Split PE and ROW workbook, which calculates the shares for the Preliminary Engineering (PE) and Right-of-Way (ROW) work type allocators that should be pasted into the *Policy* tab in the model workbook.

Base VMT Workbook

Base-year VMT is calculated in a separate supplemental workbook because of the number and variety of data sources and the size of some of the input data tables used to calculate the base VMT. For the 2011 HCAS model, the approach for calculating the base VMT was formalized with the intermediate calculations performed in a supplemental workbook and linked to the model. 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 in the Base VMT workbook.

Flat Fee

Flat Fee VMT: Chip, Sand & Gravel, and Log by Weight Class

Instructions:
1. Paste in the tabulated data for 'All Observations' and 'Observations with non-zero miles' into yellow-shaded cells.
2. Calculate Miles per Month for the non-zero miles (Column F).
3. Check formulas in right-most table where the flat fee VMT for each commodity are calculated as Months (from All Observations) multiplied by Miles per Month (from nonzero
4. Log truck VMT reported for weight classes under 56,001 pounds is excluded.

	Commodity	Weight Class	Sum of Miles (non-zero miles)	Count of Months (non-zero miles)	Count of Months (all)	Miles per Month	Total	Weight Class	Flat Fee Vehicles Log (Comm=3)	Flat Fee Vehicles S&G (Comm=2)	Flat Fee Vehicles Chip (Comm=1)
11	3	100001	830641	169	216	4,915	1,061,647.67	26001		-	-
12	3	102001	338352	80	80	4,229	338,352.00	28001		2,254	-
13	3	104001	2327901	477	525	4,880	2,562,155.19	30001		-	-
14	3	58001	1898	1	1	1,898	1,898.00	32001		-	-
15	3	78001	26034699	6247	6558	4,168	27,330,807.75	34001		-	-
16	3	80001	1807218	416	429	4,344	1,863,693.56	36001		-	-
17	3	82001	215733	52	52	4,149	215,733.00	38001		-	-
18	3	84001	1796722	445	468	4,038	1,889,586.28	40001		-	-
19	3	86001	6638992	1458	1502	4,553	6,839,345.67	42001		-	-
20	3	88001	6537302	1278	1312	5,115	6,711,220.83	44001		-	-
21	3	90001	799129	182	193	4,391	847,428.01	46001		47,902	-
22	3	92001	484980	110	114	4,409	502,615.64	48001		39,961	-
23	3	94001	1720512	396	396	4,345	1,720,512.00	50001		18,673	-
24	3	96001	1531641	363	399	4,219	1,683,539.28	52001		5,061	-
25	3	98001	2142986	447	447	4,794	2,142,986.00	54001		50,413	-
26	2	100001	58275	13	13	4,483	58,275.00	56001	-	24,685	-
27	2	104001	3623360	670	672	5,408	3,634,176.00	58001	1,898	13,835	-
28	2	28001	1932	6	7	322	2,254.00	60001	-	-	-
29	2	46001	41515	26	30	1,597	47,901.92	62001	-	-	-
30	2	48001	35088	36	41	975	39,961.33	64001	-	-	-
31	2	50001	18673	11	11	1,698	18,673.00	66001	-	-	-
32	2	52001	5061	5	5	1,012	5,061.00	68001	-	-	-

The *FlatFee* tab contains the calculation of the flat fee VMT. Carriers of certain commodities (logs, sand, gravel, and chip) can opt to pay a flat monthly fee. These carriers submit monthly reports of their mileage at their loaded operating weights. Flat fee VMT are tabulated from these Flat Fee Collections Reports in the Flat Fee VMT Axle workbook and then pasted into the yellow-shaded cells on the *FlatFee* tab in the Base VMT workbook. Because some of the monthly flat fee collections data do not report VMT, we tabulate the VMT per month from reports where miles were non-zero and then multiply by the total number of months reported in the flat fee data (all observations).

The miles per month for the non-zero mile observations is calculated in column J as the sum of miles divided by count of miles (*i.e.*, months). The flat fee VMT for each commodity by weight class is calculated by multiplying the miles per month from the non-zero mile observations by the number of months for all observations. Log truck VMT for weight class 56,001 pounds and under should be zero. Check to see that the miles per month formula is filled in for all of the flat fee records. Flat fee reports for vehicles with weights over 105,500 pounds are data entry errors and are excluded from the Flat Fee VMT table.

Pasting in the Flat Fee-All Observations and Flat Fee-Miles NonZero tables into the yellow-shaded cells will automatically update the Flat Fee VMT summary table.

WMT

WMT VMT by Weight Class and Axle Count									
Instructions:									
1. Paste WMT summary table from PostgreSQL query "wmt.sql" in yellow cells.									
2. WMT SQL CODE: SELECT weight_class, axle_count, SUM(miles) AS miles FROM wmt_payments GROUP BY axle_count, weight_class ORDER BY axle_count, weight_class									
3. Check formulas in table that sum WMT VMT by WMT vehicle tax class (axle class).									
Weight Class	Axle Count	Miles	Weight Class	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
24,001	0	30,807	26,001	3,052,725					
26,001	0	3,052,725	28,001	5,861,965					
28,001	0	5,861,965	30,001	13,343,173					
30,001	0	13,343,173	32,001	24,606,566					
32,001	0	24,606,566	34,001	5,289,833					
34,001	0	5,289,833	36,001	2,722,645					
36,001	0	2,722,645	38,001	5,032,521					
38,001	0	5,032,521	40,001	4,592,974					
40,001	0	4,592,974	42,001	3,710,212					
42,001	0	3,710,212	44,001	32,117,356					
44,001	0	32,117,356	46,001	19,666,048					
46,001	0	19,666,048	48,001	24,093,137					
48,001	0	24,093,137	50,001	14,916,577					
50,001	0	14,916,577	52,001	24,876,069					
52,001	0	24,876,069	54,001	31,632,630					
54,001	0	31,632,630	56,001	8,707,623					
56,001	0	8,707,623	58,001	8,393,070					
58,001	0	8,393,070	60,001	2,486,066					
60,001	0	2,486,066	62,001	3,281,353					
62,001	0	3,281,353	64,001	14,224,813					
64,001	0	14,224,813	66,001	3,403,410					
66,001	0	3,403,410	68,001	7,784,121					
68,001	0	7,784,121	70,001	7,863,131					
70,001	0	7,863,131	72,001	2,173,003					
72,001	0	2,173,003	74,001	6,844,482					
74,001	0	6,844,482	76,001	1,540,994					
76,001	0	1,540,994	78,001	1,086,109,676					
78,001	0	1,086,109,676	80,001		4,387,253	399,341	178,206	196,453	14,183
80,001	5	4,387,253	82,001		10,065,214	1,559,223	185,736	182,341	24,613
82,001	5	10,065,214	84,001		10,507,864	4,581,661	304,690	179,105	37,044
84,001	5	10,507,864	86,001		1,924,191	11,330,937	840,667	369,243	11,448
86,001	5	1,924,191	88,001		1,342,578	27,402,088	1,652,673	267,296	25,897
88,001	5	1,342,578	90,001		408,391	8,206,541	1,969,428	186,943	13,625

The WMT VMT are tabulated from the base-year WMT Collections Reports. The WMT data are too large for a workbook, so pre-processing requires using SQL code to produce the summary table of WMT VMT by weight and axle class, which is pasted into the yellow-shaded cells on the *WMT* tab in the Base VMT workbook. The HCAS weight class and axle class variables are created from the reported weight and axles in the WMT reports. A WMT VMT summary table is then created for each weight class and axle class.

The WMT VMT table to the right of the yellow-shaded input table is automatically updated with the new WMT VMT when the yellow-shaded input cells are updated.

RUAF

RUAF VMT by Weight Class and Axles								
Instructions:								
1. Paste the raw RUAF data into yellow-shaded cells.								
2. Assign HCAS Weight Class in column G.								
3. Check the formula that sums the RUAF VMT by weight class in column J.								
4. Column J is linked to the Base VMT tab.								
n	Issue Date	Axles	Weight	Miles	Tax	Weight Class	Weight Class	RUAF VMT
58183	1/23/07	8	160000	44	29.48	158001	80,001	-
79338	1/2/07	7	129500	33	13.53	128001	82,001	-
79350	1/2/07	7	100000	26	3.64	98001	84,001	-
79424	1/2/07	10	173000	144	63.36	172001	86,001	-
79486	1/2/07	9	161600	239.6	112.61	160001	88,001	-
79544	1/2/07	7	134600	15	7.35	134001	90,001	-
79547	1/2/07	7	128200	137	56.17	128001	92,001	-
79558	1/2/07	9	162000	47	22.09	160001	94,001	-
79571	1/2/07	7	134000	49	23.03	132001	96,001	-
79572	1/2/07	7	130000	32	13.12	128001	98,001	86,755
79574	1/2/07	12	221000	260	179.4	200001	100,001	48,094
79581	1/2/07	7	136000	27	13.23	134001	102,001	56,103
79588	1/2/07	7	140000	44	25.08	138001	104,001	143,108
79595	1/2/07	10	180000	68	32.64	178001	106,001	73,120
79596	1/2/07	8	125000	29	7.25	124001	108,001	135,776

The road use assessment fee (RUAF) records from the base year are pasted directly into the yellow-shaded cells in the *RUAF* tab. The HCAS weight class variable is calculated from the RUAF-reported vehicle weight. The RUAF collection records do not require any pre-processing. The summary RUAF table (to the right of the yellow-shaded cells) sums the VMT from the RUAF data by weight and axle class. Make sure the formulas that sum the VMT include the entire range of the RUAF data. The RUAF data provide the exact VMT by weight class for vehicles in this tax class. The model assumes there is no evasion or avoidance of the RUAF.

DMV-Other

The *DMV-Other* tab contains the DMV registration counts and assumed annual mileage used to calculate VMT for "Other" vehicle tax classes: Commercial Trucks and Buses (commercial vehicles that do not pay WMT), Tow Trucks, Farm Vehicles, Charitable Non-Profit, and State and Local Government (E-Plate). DMV registrations data are processed to

Veh_Class	Fuel	Weight_Class	Registrations	Fuel_Cat	Weight Class
	0	8,001	1	Diesel	1
	0	12,001	1	Diesel	12001
	0	14,001	1	Diesel	14001
	0	18,001	1	Diesel	18001
	0	20,001	1	Diesel	20001
	1	1	10	Gas	1
	1	4,001	6	Gas	1
	1	6,001	30	Gas	1
	1	8,001	177	Gas	1
	1	10,001	248	Gas	10001
	1	12,001	242	Gas	12001
	1	14,001	220	Gas	14001
	1	16,001	94	Gas	16001
	1	18,001	103	Gas	18001
	1	20,001	68	Gas	20001
	1	22,001	74	Gas	22001

SQL Code: select tax_class, fuel, weight_class, count(plate) as vehicles from dmv_registrations where not expired or ta

Assumptions about annual miles per registration:

Weight Class	Commercial trucks & buses	Tow Truck	Farm	Charitable Non Profit	State & Local
1	-	15,000	3,000	10,000	13,000
10001	11,000	15,000	3,000	10,000	12,000
12001	10,000	15,000	3,000	10,000	12,000
14001	9,000	15,000	3,000	10,000	12,000
16,001	8,000	15,000	3,000	10,000	12,000
18,001	8,000	15,000	3,000	10,000	12,000
20,001	8,000	15,000	3,500	10,000	12,000
22,001	8,000	15,000	3,500	10,000	12,000
24,001	8,000	15,000	3,500	10,000	12,000
26,001		15,000	3,500	10,000	11,000
28,001		15,000	3,500	10,000	11,000
30,001		15,000	3,500	10,000	11,000
32,001		15,000	3,500	10,000	11,000
34,001		15,000	3,500	10,000	11,000

Weight Class	Gas Commercial 8-26	Diesel & Other Commercial 8-26	Gas Tow Trucks	Diesel & Other Tow Trucks	Gas Farm	Diesel & Other Farm	Gas CN	Diesel & Other CN	Gas SLG	Diesel & Other SLG	School Bus (Gas)	Scho (Di
	T	T	TW	TW	F	F	CN	CN	E	E	SC	S
	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Di
1	1645	1017	163	351	2154	422	101	33	43530	14497	1359	
10,001	2905	2571	42	87	596	275	114	76	28	27	0	
12,001	1076	1554	22	96	289	168	60	44	26	12	1	
14,001	1592	3675	51	177	515	330	151	64	28	30	0	
16,001	604	2111	18	107	349	290	24	19	5	17	0	
18,001	577	2021	18	145	668	581	18	23	3	24	0	
20,001	200	574	9	23	269	191	16	18	1	9	0	
22,001	381	879	5	66	572	327	15	30	4	9	0	
24,001	1360	6461	42	596	1158	1013	37	90	9	53	0	
26,001	9	25	0	0	554	243	10	46	2	3	0	
28,001	8	27	0	0	478	307	3	18	0	37	0	
30,001	3	27	0	0	322	264	6	18	2	41	0	
32,001	4	15	0	0	104	258	1	24	2	27	0	
34,001	1	24	0	0	69	115	0	14	0	28	0	

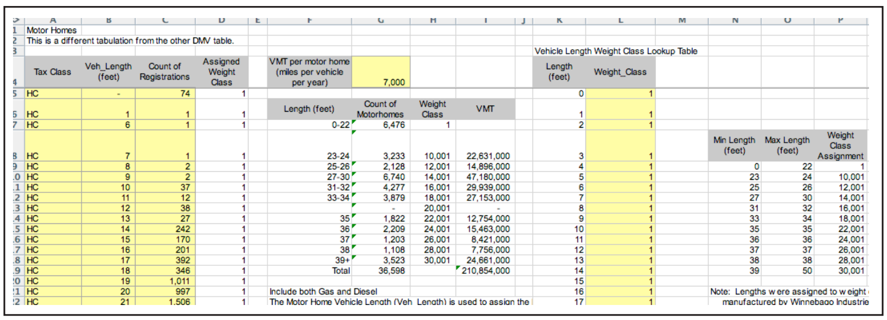
produce a summary table of registrations by vehicle class, weight class, and fuel type for each class listed above. The vehicle registrations are multiplied by assumed annual miles per vehicle to estimate the total VMT by weight class for each tax class in the *Intermediate Base VMT* tab. The summary table of DMV registrations data from the DMV SQL query should be pasted into the left-most table of yellow-shaded cells on the *DMV-Other* tab. Fuel type (gas or diesel) and weight class variables are calculated in the columns to the right of the pasted DMV registrations data.

The annual miles per vehicle assumptions for each vehicle class are in the yellow-shaded cells in the center table on the tab. The annual miles per vehicle for basic commercial trucks is set to zero because these VMT should be captured in the basic VMT calculated from the basic vehicle VMT control total. Commercial basic vehicles include hearses, ambulances, and other commercial vehicles, which register as commercial vehicles. Because these vehicles also pay fuel use tax, their VMT is included in the basic vehicle VMT estimate from the revenue forecast.

Vehicle registrations at vehicle weights greater than 200,001 pounds are data entry errors and are excluded from the VMT calculations. Commercial trucks and buses should only be registered at weights below 26,001 pounds. Assumed annual mileage for commercial trucks and buses over 26,000 pounds is left empty so that any vehicles incorrectly registered at 26,001 pounds or higher are not assigned VMT.

MotorHomes

Motor home VMT is estimated using motor home vehicle counts from the DMV registrations data and an assumed annual VMT of 7,000 per vehicle. The summary table of DMV registrations for motor homes (plate designated as HC) is pasted into the yellow-shaded cells on the left side of the *MotorHomes* tab. The annual VMT per vehicle assumption is the yellow-shaded single cell at the top center of the *MotorHomes* tab.



Motor Homes

This is a different tabulation from the other DMV table.

Tax Class	Veh_Length (feet)	Count of Registrations	Assigned Weight Class
HC	-	74	1
HC	1	1	1
HC	6	1	1
HC	7	1	1
HC	8	2	1
HC	9	2	1
HC	10	37	1
HC	11	12	1
HC	12	38	1
HC	13	27	1
HC	14	242	1
HC	15	170	1
HC	16	201	1
HC	17	392	1
HC	18	346	1
HC	19	1,011	1
HC	20	997	1
HC	21	1,506	1

VMT per motor home (miles per vehicle per year): 7,000

Length (feet)	Count of Motorhomes	Weight Class	VMT
0-22	6,476	1	
23-24	3,233	10,001	22,631,000
25-26	2,128	12,001	14,896,000
27-30	6,740	14,001	47,180,000
31-32	4,277	16,001	29,939,000
33-34	3,879	18,001	27,153,000
	-	20,001	-
35	1,822	22,001	12,754,000
36	2,209	24,001	15,463,000
37	1,203	26,001	8,421,000
38	1,108	28,001	7,756,000
39+	3,523	30,001	24,661,000
Total	36,598		210,854,000

Include both Gas and Diesel

The Motor Home Vehicle Length (Veh_Length) is used to assign the

Vehicle Length Weight Class Lookup Table

Length (feet)	Weight_Class
0	1
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1

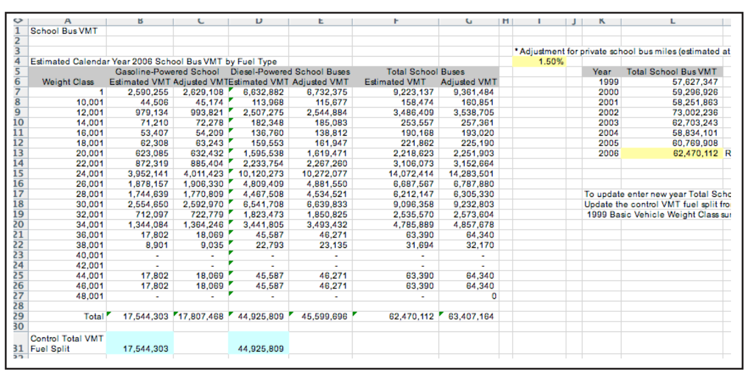
Min Length (feet)	Max Length (feet)	Weight Class Assignment
0	22	1
23	24	10,001
25	26	12,001
27	30	14,001
31	32	16,001
33	34	18,001
35	35	22,001
36	36	24,001
37	37	26,001
38	38	28,001
39	50	30,001

Note: Lengths were assigned to weight manufactured by Winnebago Industrie

Because motor home vehicle weight information is not available from the DMV registrations data for motor homes, the vehicle length (feet) field is used to assign the motor home weight classes. Information on manufacturer motor home vehicle specifications was used to develop a table of motor home weight classes by vehicle lengths. The assumed weight class and vehicle length categories are assumptions in the yellow-shaded cells in a table on the right-hand side of the *MotorHomes* tab.

SchoolBus

The *SchoolBus* tab contains 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* tab is applied to the 2006 school bus VMT to



School Bus VMT

Estimated Calendar Year 2006 School Bus VMT by Fuel Type

Weight Class	Gasoline-Powered School Estimated VMT	Gasoline-Powered School Adjusted VMT	Diesel-Powered School Buses Estimated VMT	Diesel-Powered School Buses Adjusted VMT	Total School Buses Estimated VMT	Total School Buses Adjusted VMT
1	2,590,255	2,629,108	6,632,882	6,732,375	9,223,137	9,361,484
10,001	44,506	45,174	113,968	115,677	158,474	160,851
12,001	979,134	993,821	2,507,275	2,544,884	3,486,409	3,538,705
14,001	71,210	72,278	182,348	185,083	253,557	257,361
16,001	53,407	54,209	136,760	138,812	190,168	193,020
18,001	62,308	63,243	159,553	161,947	221,862	225,190
20,001	623,085	632,432	1,595,538	1,619,471	2,218,623	2,251,903
22,001	872,319	885,404	2,233,754	2,267,260	3,106,073	3,152,664
24,001	3,952,141	4,011,423	10,120,273	10,272,077	14,072,414	14,283,501
26,001	1,878,157	1,906,330	4,809,409	4,881,550	6,687,567	6,787,880
28,001	1,744,639	1,770,809	4,467,508	4,534,521	6,212,147	6,305,330
30,001	2,554,650	2,592,970	6,541,708	6,639,833	9,096,358	9,232,803
32,001	712,097	722,779	1,823,473	1,850,825	2,535,570	2,573,604
34,001	1,344,084	1,364,246	3,441,805	3,493,432	4,785,889	4,857,678
36,001	17,802	18,069	45,587	46,271	63,390	64,340
38,001	8,901	9,035	22,793	23,135	31,694	32,170
40,001	-	-	-	-	-	-
42,001	-	-	-	-	-	-
44,001	17,802	18,069	45,587	46,271	63,390	64,340
46,001	17,802	18,069	45,587	46,271	63,390	64,340
48,001	-	-	-	-	-	0
Total	17,544,303	17,807,468	44,925,809	45,599,696	62,470,112	63,407,164
Control Total VMT Fuel Split	17,544,303		44,925,809			

* Adjustment for private school bus miles (estimated at

1.50%

Year	Total School Bus VMT
1999	57,627,347
2000	59,296,926
2001	58,251,863
2002	73,002,236
2003	62,703,243
2004	58,834,101
2005	60,769,908
2006	62,470,112

To update enter new year Total Scho

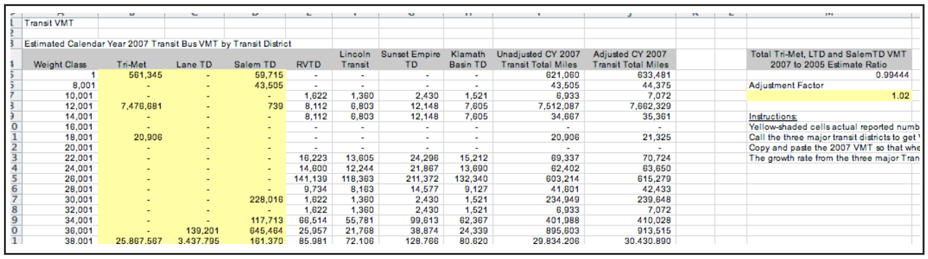
Update the control VMT fuel split fro

1999 Basic Vehicle Weight Class su

determine the fuel-type split for the school bus VMT. The control total VMT by weight class are also adjusted by an assumed percent to account for private school bus miles not included in the DOE estimated school bus VMT.

Transit

The *Transit* tab estimates 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. To update this tab, the transit bus VMT by weight class for Tri-Met, Lane Transit District, and Salem 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. A final adjustment factor is used to adjust the transit VMT reported by the seven transit districts. The adjustment factor is in a yellow-shaded cell to the right of the base-year table. The adjustment factor is an artifact from the original 2005 transit VMT calculations provided by ODOT.


Transit VMT

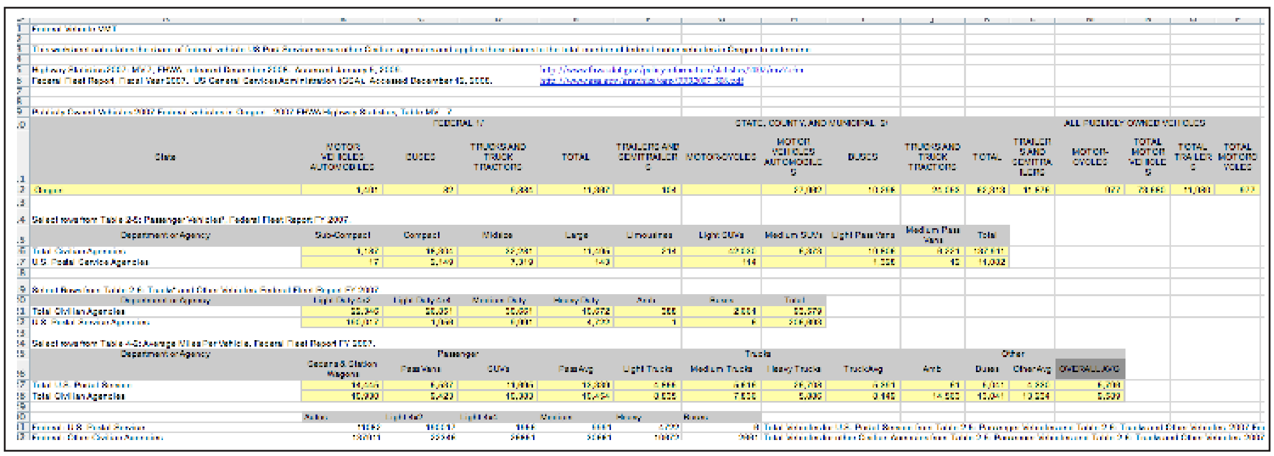
Estimated Calendar Year 2007 Transit Bus VMT by Transit District

Weight Class	Tri-Met	Lane TD	Salem TD	RVTD	Lincoln Transit	Sunset Empire TD	Klamath Basin TD	Unadjusted CY 2007 Transit Total Miles	Adjusted CY 2007 Transit Total Miles
1	561,345	-	59,715	-	-	-	-	621,060	633,481
8,001	-	-	43,505	-	-	-	-	43,505	44,375
10,001	-	-	-	1,622	1,360	2,430	1,521	6,933	7,072
12,001	7,476,681	-	739	8,112	6,803	12,148	7,605	7,512,087	7,662,329
14,001	-	-	-	8,112	6,803	12,148	7,605	34,667	35,361
16,001	-	-	-	-	-	-	-	-	-
18,001	20,906	-	-	-	-	-	-	20,906	21,325
20,001	-	-	-	-	-	-	-	-	-
22,001	-	-	-	16,223	13,605	24,296	15,212	69,337	70,724
24,001	-	-	-	14,600	12,244	21,867	13,690	62,402	63,650
26,001	-	-	-	141,139	118,363	211,372	132,340	603,214	615,279
28,001	-	-	-	9,734	8,163	14,577	9,127	41,601	42,433
30,001	-	-	228,016	1,622	1,360	2,430	1,521	234,949	239,648
32,001	-	-	-	1,622	1,360	2,430	1,521	6,933	7,072
34,001	-	-	117,713	66,514	55,781	99,613	62,367	401,988	410,028
36,001	-	139,201	645,464	25,957	21,768	38,874	24,339	895,603	913,515
38,001	25,867,567	3,437,795	161,370	85,981	72,106	128,766	80,620	29,834,206	30,430,890

Total Tri-Met, LTD and SalemTD VMT 2007 to 2005 Estimate Ratio
0.99444
Adjustment Factor
1.02

Instructions:
Yellow-shaded cells actual reported numb
Call the three major transit districts to get
Copy and paste the 2007 VMT so that whe
The growth rate from the three major Tran

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 on the *Federal* tab. The input data on the *Federal* tab are used with the Federal Spread Weights to calculate the federal VMT in the *Federal Summary* tab. 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* 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.

Fed Weight Class Spread

The *Federal* tab contains federal VMT and number of federal vehicles. The *Fed Weight Class Spread* tab uses the share of VMT for school buses (*SchoolBus* tab) and transit buses (*Transit* tab) by weight classes to spread the federal bus VMT across vehicle weight classes. Similarly, the State and Local Government (SLG) VMT (final estimates calculated in the *Intermediate Base VMT* tab) are used to spread the federal heavy vehicle VMT across weight classes. This tab essentially creates the shares or weights for each weight class, which are then applied to the federal VMT input from the *Federal* tab.

All of the calculations on this tab are linked to other tabs in the Base VMT workbook. The analyst can 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* tab.

Spread Federal VMT across Weight Classes using the Distribution of Bus and SLG VMT

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
1	2,629,108	6,732,375	677,856	10,039,340	0.0947	101093.3	565,929,000	188,461,000	754,390,000			0	0.75
10,001	45,174	115,677	7,072	167,923	0.0016	1690.933	336,000	324,000	660,000	0.364238		3589873	0.51
12,001	993,821	2,544,884	7,662,329	11,201,034	0.1056	112791.3	312,000	144,000	456,000	0.251656		2480276	0.68
14,001	72,278	185,083	35,361	292,722	0.0028	2947.624	336,000	360,000	696,000	0.384106		3785685	0.48
16,001	54,209	138,812	0	193,020	0.0018	1943.661	60,000	204,000	264,000		0.060426	379651.1	0.23
18,001	63,243	161,947	21,325	246,514	0.0023	2482.328	36,000	288,000	324,000		0.074159	465935.4	0.11
20,001	632,432	1,619,471	0	2,251,903	0.0212	22676.03	12,000	108,000	120,000		0.027466	172568.7	0.10
22,001	885,404	2,267,260	70,724	3,223,388	0.0304	32458.62	48,000	108,000	156,000		0.035706	224339.3	0.31
24,001	4,011,423	10,272,077	63,650	14,347,150	0.1353	144471.8	108,000	636,000	744,000		0.170291	1069926	0.15
26,001	1,906,330	4,881,550	615,279	7,403,159	0.0698	74547.73	22,000	33,000	55,000		0.012589	79093.98	0.40
28,001	1,770,809	4,534,521	42,433	6,347,762	0.0599	63920.18	0	407,000	407,000		0.093156	585295.4	0.00
30,001	2,592,970	6,639,833	239,648	9,472,451	0.0893	95384.92	22,000	451,000	473,000		0.108263	680208.2	0.05
32,001	722,779	1,850,825	7,072	2,580,676	0.0243	25986.68	22,000	297,000	319,000		0.073014	458745.1	0.07
34,001	1,364,246	3,493,432	410,028	5,267,706	0.0497	53044.32	0	308,000	308,000		0.070497	442926.3	0.00
36,001	18,069	46,271	913,515	977,855	0.0092	9846.729	44,000	660,000	704,000		0.161135	1012403	0.06
38,001	9,035	23,135	30,430,890	30,463,060	0.2873	306754.5	11,000	11,000	22,000		0.005035	31637.59	0.50
40,001	0	0	0	0	0.0000	0	11,000	22,000	33,000		0.007553	47456.39	0.33
42,001	0	0	1,252,127	1,252,127	0.0118	12608.56	33,000	22,000	55,000		0.012589	79093.98	0.60

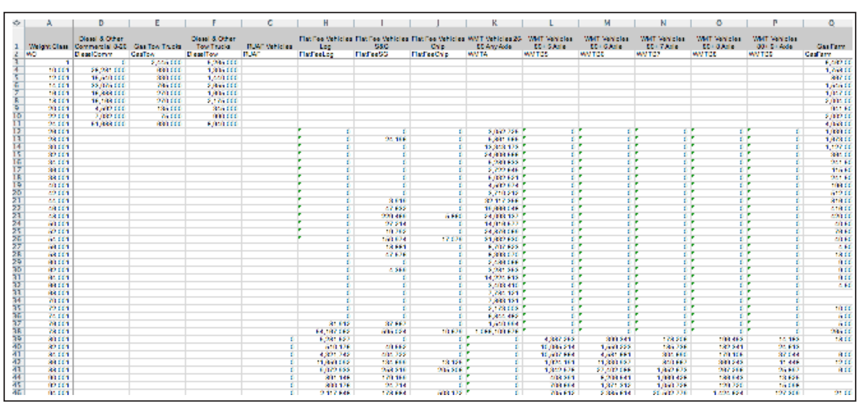
Federal Summary

The *Federal Summary* tab sums the federal VMT by weight class from the *Federal* tab and the *Fed Weight Class Spread* tab. Federal VMT for basic vehicles is the sum of the basic VMT from the *Federal* tab and the federal bus VMT from the *Fed Weight Class Spread* tab. Federal VMT for vehicles 10,001 pounds and above are the federal bus and truck VMT from the *Fed Weight Class Spread* tab. 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.

Federal VMT Summary for Gas and Diesel Vehicles

Weight Class	Federal VMT	Federal Gas	Federal Diesel
1	60,497,247	45,383,882	15,113,365
10,001	3,591,564	1,828,433	1,763,132
12,001	2,593,068	1,774,204	818,863
14,001	3,788,632	1,828,995	1,959,637
16,001	381,595	86,726	294,869
18,001	468,418	52,046	416,371
20,001	195,245	19,524	175,720
22,001	256,798	79,015	177,783
24,001	1,214,398	176,284	1,038,114
26,001	153,642	61,457	92,185
28,001	649,216	0	649,216
30,001	775,593	36,074	739,519
32,001	484,732	33,430	451,302
34,001	495,971	0	495,971
36,001	1,022,250	63,891	958,359

Intermediate Base VMT



The *Intermediate Base VMT* tab consolidates all of the vehicle tax class VMT from the individual vehicle class tabs. The *Intermediate Base VMT* tab is so named because this tab contains the raw VMT numbers prior to the control total adjustment for the basic and medium-heavy vehicle weight classes. The *Intermediate Base VMT* tab references each tab in the workbook. For most of the vehicle classes, this tab links the vehicle VMT by weight class into the correct column for the final format of the *Base VMT (no WMTEvasion)* tab. The VMT per year and the annual vehicle registrations are multiplied in this worksheet for the "Other" vehicle classes from the *DMV-Other* tab.

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 *Intermediate Base VMT* tab. The VMT estimates for the base year are the control totals for the basic vehicle and medium-heavy vehicle classes. 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 *Intermediate Base VMT* tab and the *Base VMT (no WMTEvasion)* tab 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.

	AD	AE	AF	AG	AH	AI	AJ	AK
	Difference							
	(33,738,194,704)							
B	(118,208,606)	18%	**1.22**					
		Kavanaugh's Forecast (FSB-Method Estimation of Statewide VMT-Forecasts CY2008-2010) (10/8/08)						
		Light Vehicles	Medium Heavy	Heavy	Total			
	2007 Preliminary	34,579,899,291	646,317,978	1,959,608,476	37,185,825,745			
			0					

Base VMT (no WMTEvasion)

The *Base VMT (no WMTEvasion)* tab is the final worksheet in the Base VMT workbook and is linked to the *Base VMT* worksheet in the HCAS model. The tab contains the calculated base-year VMT for each vehicle tax class by weight class and 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 "No WMTEvasion" in the tab name is to indicate that the WMT VMT reflect the WMT VMT reported in the WMT Collection Reports. WMT VMT are adjusted to include the assumed WMT evasion rate in the *Base VMT* tab in the HCAS Model workbook.

	M	N	O	P	Q	R	S
1	WMT Vehicles 80+ 6 Axle	WMT Vehicles 80+ 7 Axle	WMT Vehicles 80+ 8 Axle	WMT Vehicles 80+ 9+ Axle	Gas Farm	Diesel & Other Farm	Gas CN
3	0	0	0	0	6,462,000	1,266,000	1,010
4	0	0	0	0	2,151,499	1,009,663	1,395
5	0	0	0	0	1,061,064	616,812	734
6	0	0	0	0	1,890,823	1,211,595	1,847
7	0	0	0	0	1,281,354	1,075,750	293
8	0	0	0	0	2,452,562	2,133,142	220
9	0	0	0	0	1,152,239	818,133	195
10	0	0	0	0	2,450,115	1,400,678	183
11	0	0	0	0	4,960,197	4,339,102	452
81	0	0	0	0	0	0	
82	0	0	0	0	0	0	
83	0	0	0	0	0	0	
84	0	0	0	0	0	0	
85	0	0	0	0	0	0	
86	0	0	0	0	0	0	
87	0	0	0	0	0	0	
88	0	0	0	0	0	0	
89	0	0	0	0	0	0	
90	0	0	0	0	0	0	
91	0	0	0	0	0	0	
92	0	0	0	0	0	0	
93	0	0	0	0	0	0	
94	0	0	0	0	0	0	
95	0	0	0	0	0	0	
96	0	0	0	0	0	0	
97	0	0	0	0	0	0	
98	0	0	0	0	0	0	
99	0	0	0	0	0	0	
100	61,257,514	158,742,780	166,420,285	3,549,052			
101							

The basic vehicle VMT for cars is equal to the basic vehicle control total minus the VMT reported for the other vehicle tax classes on the *Intermediate Base VMT* tab.

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) from the *Intermediate Base VMT* tab. VMT for vehicles in the 26,001-pound weight class and above are equal to the VMT in the *Intermediate Base VMT* tab. The references and calculations on this tab are automatically updated or calculated when the rest of the tabs in the workbook are changed.

Once the Base VMT workbook has been completely updated and reviewed, the user should update the linked *Base VMT* tab in the HCAS Model workbook by opening the workbook and updating the links.

Split PE and ROW Workbook

The Split PE and ROW workbook calculates the split of the Preliminary Engineering (PE) and Right-of-Way (ROW) costs between modernization and preservation projects in order to determine the cost allocator shares for the PE and ROW work types on the *Policy* tab in the HCAS model.

Split Non-Construction

The *Split Non-Construction* tab determines the shares to assign for the allocation of PE and ROW costs. The updated state- and federal-funded PE and ROW non-project costs from the *Non-Project Costs* tab in the HCAS model should be pasted into the yellow-shaded cells on this tab. The state-funded PE (ROW) amount should be the sum of the state- and bond-funded PE (ROW) work type from the *Non-Project Costs* tab. The blue-shaded cells on this tab are automatically updated from the *Proj Costs Mod and Pres* tab.

The orange-shaded cells at the bottom of the tab are the shares of PE and ROW costs that are allocated to modernization and preservation projects. The shares for PE (work type 1) and ROW (work type 2) should be pasted into the appropriate “Shares” for work types 1 and 2 on the *Policy* tab in the HCAS Model workbook once all of the tabs in the Split PE and ROW workbook are updated.

Category	State	Federal	Total	%State	
PE	47,600,072	93,856,167	141,456,239	33.65%	Nor
ROW	74,414,127	47,471,883	121,886,010	61.05%	Nor
MOD	178,311,686	290,689,242	469,000,927	38.02%	
PRES	326,521,784	467,597,085	794,118,869	41.12%	
CONST	504,833,470	758,286,326	1,263,119,796	39.97%	
TOTAL	626,847,669	899,614,376	1,526,462,045	41.07%	
Before Studded Tires	**State**	**Federal**	**Total**	**%State**	
PE-MOD	17,674,078	34,849,133	52,523,211	33.65%	
ROW-MOD	26,283,734	18,198,358	44,482,091	59.09%	
CONST-MOD	178,311,686	290,689,242	469,000,927	38.02%	
TOTAL-MOD	222,269,497	343,736,732	566,006,229	39.27%	
PE-PRES	29,925,994	59,007,034	88,933,028	33.65%	
ROW-PRES	48,130,393	29,273,525	77,403,919	62.18%	
CONST-PRES	326,521,784	467,597,085	794,118,869	41.12%	
TOTAL-PRES	404,578,171	555,877,645	960,455,816	42.12%	
TOTAL	626,847,669	899,614,376	1,526,462,045	41.07%	
% of PE that is Mod	37.13%	37.13%	37.13%		
% of PE that is Pres	62.87%	62.87%	62.87%		
% of ROW that is Mod	35.32%	38.34%	36.49%		
% of ROW that is Pres	64.68%	61.66%	63.51%		
% of Mod that is PE	7.95%	10.14%	9.28%		
% of Pres that is PE	7.40%	10.62%	9.26%		
% of Mod that is ROW	11.83%	5.29%	7.86%		
% of Pres that is ROW	11.90%	5.27%	8.06%		
After Studded Tires	**State**	**Federal**	**Total**	**%State**	
PE-MOD	17,674,078	34,849,133	52,523,211	33.65%	
ROW-MOD	26,283,734	18,198,358	44,482,091	59.09%	
CONST-MOD	178,311,686	290,689,242	469,000,927	38.02%	
TOTAL-MOD	222,269,497	343,736,732	566,006,229	39.27%	
PE-PRES	29,478,131	58,123,953	87,602,083	33.65%	
ROW-PRES	48,130,393	29,273,525	77,403,919	62.18%	
CONST-PRES	325,182,273	455,893,648	781,075,921	41.63%	
TOTAL-PRES	402,790,797	543,291,126	946,081,924	42.57%	
TOTAL	625,060,295	887,027,858	1,512,088,153	41.34%	
% of PE that is Mod	37.48%	37.48%	37.48%	Share 1 for PE	
% of PE that is Pres	62.52%	62.52%	62.52%	Share 2 for PE	
% of ROW that is Mod	35.32%	38.34%	36.49%	Share 1 for ROW	
% of ROW that is Pres	64.68%	61.66%	63.51%	Share 2 for ROW	
% of Mod that is PE	7.95%	10.14%	9.28%		
% of Pres that is PE	7.32%	10.70%	9.26%		
% of Mod that is ROW	11.83%	5.29%	7.86%		
% of Pres that is ROW	11.95%	5.39%	8.18%		

Proj Costs Mod and Pres

Paste the input from the *Project Costs* tab into the yellow-shaded cells on the *Proj Costs Mod and Pres* tab. The project costs data are used to determine the share of preservation and modernization project expenditures by funding source on the *Split Non-Construction* tab.

Funding	Worktype	Functional Class	Bridge Type	Expenditure	Key Number		WORK TYPE	WORK CATEGORY	federal	state	bond
bond	68	0	3	27475266.42	14259		1	PE	0	0	
bond	14	0	3	25978671.16	15228		2	ROW	0	0	
bond	68	0	3	23913666.86	14032	Instructions:	3	modernization	542600.079	398047.502	
federal	15	0	0	19459227.36	14494	Paste in the Project cost from HCAS Model workbook Proj	4	modernization	0	0	
federal	26	0	0	18033502.04	14684		5	modernization	32939121.3	10638493.8	10644
bond	14	0	3	18013332.01	14610		6	modernization	0	0	
federal	48	0	0	13511361.25	12754		7	modernization	0	0	
federal	48	0	0	13494793.5	12753		8	modernization	0	0	
state	48	0	0	12357833	13890		9	modernization	66227968.8	12851575.8	10197
state	48	0	0	12357833	13891		10	preservation	0	0	
federal	33	0	0	12000000	15110		11	preservation	241135244	48777236.1	15971
federal	68	0	3	11350030.25	14949		12	preservation	0	0	
bond	15	0	0	11329769	14049		13	bridge-mod	218433.169	152624.728	12108
federal	11	0	3	11181458.09	12692		14	bridge-pres	88609893.1	12423316.4	1610?
bond	14	0	3	10944221.88	14031		15	bridge-pres	81040280.4	10958353.5	65930
bond	14	0	3	10712663	14043		16	modernization	544116.008	55889.4088	29888
federal	11	0	0	10597354.94	15740		17	modernization	1790899.31	204976.44	
federal	20	0	0	10426133	13933		18	modernization	0	0	
federal	5	0	0	10193597.9	13981		19	bridge-mod	15077225.4	5082438.71	68560

Studded Tires

The *Studded Tires* tab contains the studded-tire-related cost breakdown used to adjust the preservation and modernization project costs for the PE and ROW split. Data from the *Studded Tires in Oregon* study are used to adjust the preservation and modernization costs for studded tire damage. No user input is necessarily required on this tab, but the funding shares and amounts can be adjusted if new data or information are available (yellow-shaded cells).

A	B	C	D
Studded Tires Adjustment for PE and ROW Split			
Studded Tire Damage	14,373,893		From Ta
Engineering %	9.26%		Base Lif
Construction %	90.74%		
Construction $	13,042,948		
Engineering $	1,330,945		Year
			2001
Engineering % State	33.65%		2002
State Engineering $	447,863		2003
Fed Engineering $	883,082		2004
			2005
% State	10.27%		
State Construction $	1,339,511		
Fed Construction $	11,703,437		*Studde
			Table 5.
			Base
State $	1,787,374		life
Fed $	12,586,518		1995
			1996

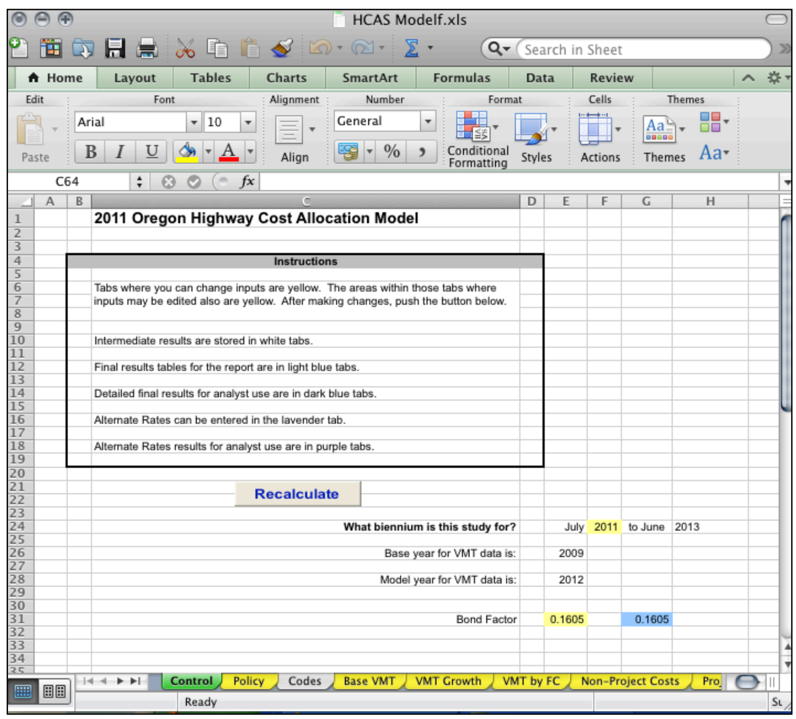
Tab-by-Tab Explanation of HCAS Model

This section provides a tab-by-tab explanation of the tabs in the HCAS model. Following the tab-by-tab explanation of the input tabs are descriptions of how to recalculate the model and audit the model output, and then a tab-by-tab explanation of the intermediate output tabs and the result tabs.

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, *Name*, *Define*, select the named range, and review and change (if necessary) the *Refers to* cell references.

Excel Macros must be enabled to recalculate the model. To enable Excel Macros, a message should appear when opening the Excel workbook asking whether to open with macros enabled. If this message does not appear, or it is unclear whether macros are enabled, in the Excel workbook, go to *Tools*, *Options*, click the *Security* tab, and under *Macro Security*, select *Medium* and click *Okay*. Exit Excel and open the HCAS model. The next time the Model workbook is opened the enable macro message should appear.

Control



The *Control* tab contains the “Recalculate” button, which will run the HCAS model. The “Recalculate” button calls the Excel VBA Module (macro), which captures the input data from the HCAS Model workbook and then calls the HCASModule (Python) to perform the Model calculations.

Enter the biennium study period and the bond factor in the *Control* tab.

To update the study biennium, enter the first year of the biennium in the yellow-shaded cell following the question *“What biennium is this study for?”* 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 in the blue-shaded cell and then pasting into the yellow-shaded bond factor cell. 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 2011 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.

Codes

The *Codes* tab contains the lookup codes with their descriptive names for the project Work Type, Facility Class, and Available Bridge Types (top three tables) and the Summary Work Types and Summary Weight Classes (below the Work Types and Facility Class tables). The Summary Work Types and the Summary Weight Class lookup tables are used by the model to aggregate the costs to allocate and allocated costs in the intermediate output tables.

Available Work Type Codes			Available Facility Class Codes		
Work Type	Work Type Description		Facility Class	Functional Class	Ownership
1	Preliminary and Construction Engineering (and etc.)		-4	All Urban	Any
2	Right of Way (and Utilities)		-3	All Rural	Any
3	Grading and Drainage		-2	Any	Local
4	New Pavements-Rigid		-1	Any	Any
5	New Pavements-Flexible		0	Any	State
6	New Shoulders-Rigid		1	1-Rural Interstate	1-State
7	New Shoulders-Flexible		2	2-Rural Other Principal Arterial	1-State
8	Pavement and Shoulder Reconstruction-Rigid		3	6-Rural Minor Arterial	1-State
9	Pavement and Shoulder Reconstruction-Flexible		4	7-Rural Major Collector	1-State
10	Pavement and Shoulder Rehab-Rigid		5	8-Rural Minor Collector	1-State
11	Pavement and Shoulder Rehab-Flexible		6	9-Rural Local	1-State
12	Pavement and Shoulder Rehab-Other		7	11-Urban Interstate	1-State
13	New Structures		8	12-Urban Other Freeway	1-State
14	Replacement Structures		9	14-Urban Other Principal Arterial	1-State
15	Structures Rehabilitation		10	16-Urban Minor Arterial	1-State
16	Climbing Lanes		11	17-Urban Collector	1-State
17	Truck Weight/Inspection Facilities		12	19-Urban Local	1-State
18	Truck Escape Ramps		13	1-Rural Interstate	2-County
19	Interchanges		14	2-Rural Other Principal Arterial	2-County
20	Roadside Improvements		15	6-Rural Minor Arterial	2-County
21	Safety Improvements		16	7-Rural Major Collector	2-County
22	Traffic Service Improvements		17	8-Rural Minor Collector	2-County
23	Other Construction (modernization)		18	9-Rural Local	2-County
24	Other Construction (preservation)		19	11-Urban Interstate	2-County
25	Surface and Shoulder Maintenance-Rigid		20	12-Urban Other Freeway	2-County

The user should refer to the tables in the *Codes* tab to look up the description corresponding to a numeric code and also to determine the valid range of codes for the work types, facility classes, or bridge types in the user input tabs.

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.

Work Type	Work Type Description	Allocator 1	Share 1	Allocator 2	Share 2
1	Preliminary and Construction Engineering (and etc.)	Congested PCE	37.5%	Other Construction	62.5%
2	Right of Way (and Utilities)	Congested PCE	35.3%	Other Construction	64.7%
3	Grading and Drainage	Congested PCE	100.0%		0.0%
4	New Pavements-Rigid	Congested PCE	6.9%	Rigid Pave	93.1%
5	New Pavements-Flexible	Congested PCE	4.5%	Flex Pave	95.5%
6	New Shoulders-Rigid	Congested PCE	100.0%		0.0%
7	New Shoulders-Flexible	Congested PCE	100.0%		0.0%
8	Pavement and Shoulder Reconstruction-Rigid	Congested PCE	26.9%	Rigid Pave	73.08%
9	Pavement and Shoulder Reconstruction-Flexible	Congested PCE	24.5%	Flex Pave	75.54%
10	Pavement and Shoulder Rehab-Rigid	All VMT	26.9%	Rigid Pave	73.08%
11	Pavement and Shoulder Rehab-Flexible	All VMT	24.5%	Flex Pave	75.54%
12	Pavement and Shoulder Rehab-Other	All VMT	100.0%		0.0%
13	New Structures	None-Bridge Split	100.0%		0.0%
14	Replacement Structures	None-Bridge Split	100.0%		0.0%
15	Structures Rehabilitation	None-Bridge Split	100.0%		0.0%
16	Climbing Lanes	Uphill PCE	100.0%		0.0%
17	Truck Weight/Inspection Facilities	Over 26 VMT	100.0%		0.0%
18	Truck Escape Ramps	Over 26 VMT	100.0%		0.0%
19	Interchanges	None-Bridge Split	100.0%		0.0%
20	Roadside Improvements	All VMT	100.0%		0.0%
21	Safety Improvements	Congested PCE	100.0%		0.0%
22	Traffic Service Improvements	Congested PCE	100.0%		0.0%
23	Other Construction (modernization)	Other Construction	100.0%		0.0%
24	Other Construction (preservation)	All VMT	100.0%		0.0%
25	Surface and Shoulder Maintenance-Rigid	All VMT	26.9%	Rigid Pave	73.1%
26	Surface and Shoulder Maintenance-Flexible	All VMT	24.5%	Flex Pave	75.5%
27	Surface and Shoulder Maintenance-Other	All AMT	100.0%		0.0%
28	Drainage Facilities Maintenance	All VMT	100.0%		0.0%
29	Structures Maintenance	All VMT	100.0%		0.0%

The user can 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.

Base VMT

The *Base VMT* tab contains the base year VMT by weight class and vehicle tax class. The *Base VMT* tab is linked to the Base VMT supplemental workbook. Once the Base VMT workbook has been updated, update the linked data when prompted when opening the HCAS Model workbook. The linked data can also be updated by going to the *Edit* menu, choosing *Links*, and then clicking *Update Values* for the Base VMT workbook link.

The WMT evasion factor[4] adjusts the WMT VMT to account for the additional VMT not reported for WMT payments. The WMT VMT evasion factor is applied to the VMT for WMT vehicle classes in this tab. The WMT evasion rate is a user-specified assumption located on the *Revenue* tab.

Oregon Transportation Economic and Revenue Forecast								
Table 1. FSB-Method Estimation of Statewide VMT - Forecasts CY2008-2010								
Dec-08								
	Year	Light Vehicles /1	Annual % Change	Med Heavy /2	Annual % Change	Heavy /3	Annual % Change	Total	Annual % Change
	2003	33,675,350,270	-	578,634,515	-	1,833,137,935	-	36,087,122,720	-
	2004	33,828,433,633	0.45%	602,321,904	4.1%	1,885,148,472	2.84%	36,315,904,009	0.6%
	2005	34,288,770,342	1.36%	615,515,525	2.2%	1,983,676,146	5.23%	36,887,962,012	1.6%
	2006	34,717,242,607	1.25%	632,405,067	2.3%	2,006,490,550	1.15%	37,353,575,732	1.3%
Base Year:	**2007**	**34,579,899,291**	**-0.40%**	**646,317,978**	**2.2%**	**1,959,608,476**	**-2.34%**	**37,185,825,745**	**-0.4%**
	2008	34,476,159,593	-0.30%	643,086,388	-0.50%	1,957,648,867	-0.10%	37,076,894,849	-0.3%
	2009	33,372,922,486	-3.20%	675,240,707	5.00%	1,846,062,882	-5.70%	35,894,226,076	-3.2%
Forecast Year:	**2010**	**34,207,245,548**	**2.50%**	**692,121,725**	**2.5%**	**1,942,058,152**	**5.20%**	**36,841,425,425**	**2.6%**
	Based on taxable motor fuels consumption								
2	Based on a new prototype framework for medium heavy vehicle stock and fuel consumption								
3	Based on HUS for 2007.								

The base VMT are used in the HCAS model to calculate the model year VMT. The VMT are used to allocate costs and attribute revenues by vehicle tax and weight class.

VMT Growth

The VMT growth rates are calculated from the change in VMT from the base year to the forecast year in the ODOT Economic and Revenue Forecast. To update the growth rates, paste the ODOT Economic and Revenue Forecast VMT into the yellow-shaded cells under the table titled "Oregon Transportation Economic and Revenue Forecast" so that the base year and forecast year match the Base Year and Forecast Year row names to the left of the year column. The compound VMT growth rates are automatically calculated for light, medium-heavy, and heavy vehicle classes below the VMT forecast table. In the middle of the tab, the *Target Growth Rates* for the three vehicle class groups are automatically set to the new compound growth rates.

	A	B	C	D	E	F
1	Weight Class	Growth Rate		VMT Growth Rates by Weight Class		
2	1	-0.36%				
3	10,001	2.31%				
4	12,001	2.31%		Target rate		Group average rate
5	14,001	2.31%		-0.36%	basic	-0.36%
6	16,001	2.31%		2.31%	medium	2.31%
7	18,001	2.31%		-0.30%	heavy	-0.30%
8	20,001	2.31%				
9	22,001	2.31%				
10	24,001	2.31%				
11	26,001	-9.600%				
12	28,001	-6.600%				
13	30,001	-2.000%				
14	32,001	2.100%				
15	34,001	-3.800%				
16	36,001	-7.600%				
17	38,001	-4.350%				
18	40,001	-4.350%				
19	42,001	-13.000%				
20	44,001	-7.650%				
21	46,001	-1.650%				
22	48,001	-1.650%				
23	50,001	-0.400%				
24	52,001	1.200%				
25	54,001	3.300%				
26	56,001	3.050%				
27	58,001	0.500%				
28	60,001	1.200%				
29	62,001	-1.800%				
30	64,001	0.900%				
31	66,001	-5.650%				
32	68,001	0.500%				
33	70,001	2.300%				
34	72,001	-2.102%				

On the far left-hand side of the tab, the VMT growth rates by weight class for the basic and medium vehicle classes are set equal to their calculated compound vehicle class growth rates.

Also on the far left-hand side of the tab, the heavy vehicle growth rates in the yellow-shaded cells should be 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. In past studies an expert from ODOT familiar with heavy vehicles in Oregon has made adjustments to the VMT growth rates for the heavy vehicles (vehicles 26,001 pounds and up). 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.

Because the group-adjusted growth rates are calculated using the base-year VMT, the heavy vehicle class growth rates should not be adjusted until the Base VMT workbook has been completely updated and the HCAS Model workbook link to the Base VMT workbook data has been updated.

The VMT growth rates by weight class are applied to the base VMT data to calculate the model-year VMT.

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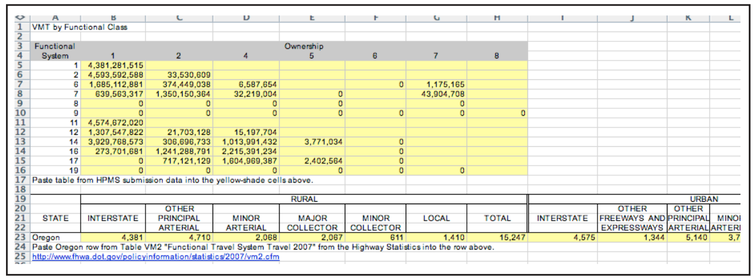
[4] WMT evasion factor is calculated as one divided by one minus the WMT evasion percent (1/(1-WMT Evasion).

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 to produce the output in the *Master VMT* tab.

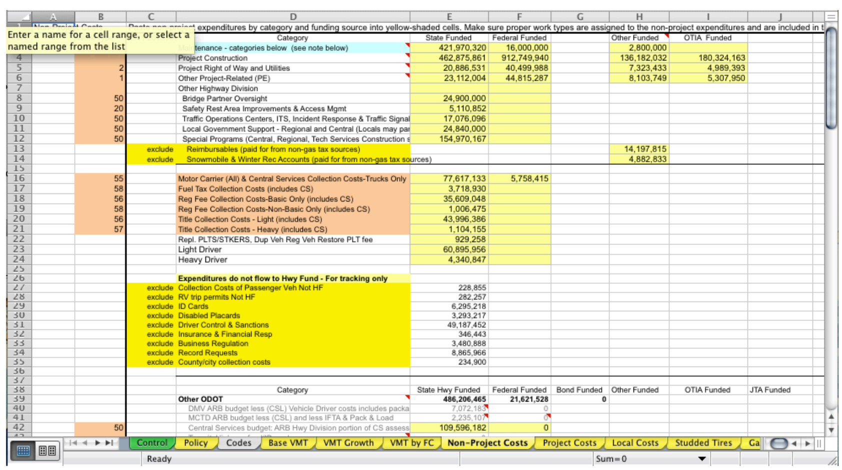
Two data sources are used to update the input on this tab: Oregon's Highway Performance Monitoring System (HPMS) submission data and data from the annual Federal Highway Administration (FHWA) *Highway Statistics* report.

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.

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.

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 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 yellow-shaded tables of the *Non-Project Costs* tab. When pasting the data into the yellow-shaded cells, 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.

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 can change the *Project Costs* input data by pasting project expenditures into the yellow-shaded cells. The model ignores entries in the Memo column and stops reading data at the first empty row, so be sure eliminate spaces between entries.

	Funding	Work Type	Functional Class	Bridge Type	Dollars	Key Number
2	other	15	0	0	18,691	16284
3	federal	15	0	0	163,304	16284
4	other	29	0	0	3,902	16283
5	federal	29	0	0	34,094	16283
6	other	29	0	0	5,134	16282
7	federal	29	0	0	44,861	16282
8	state	5	0	0	866,291	16272
9	other	5	0	0	8,759,165	16272
10	state	11	0	0	142,588	16271
11	state	9	0	0	91	16008
12	federal	9	0	0	1,082	16008
13	other	23	0	0	4,621	16006
14	federal	23	0	0	40,375	16006
15	state	44	0	0	38,156	16005
16	federal	44	0	0	333,374	16005
17	state	22	0	0	244,079	16004
18	state	46	0	0	679,223	16003
19	federal	46	0	0	5,934,441	16003
20	state	14	0	3	84,144	15970
21	federal	14	0	3	735,178	15970
22	federal	21	0	0	257,467	15969
23	other	15	0	0	25,469	15968
24	federal	15	0	0	222,527	15968
25	state	11	0	0	815,265	15964
26	federal	11	0	0	9,663,724	15964
27	state	15	0	0	89,836	15874
28	federal	15	0	0	784,904	15874
29	state	15	0	0	73,085	15846
30	federal	15	0	0	638,551	15846
31	state	11	0	3	90,799	15845
32	federal	11	0	3	793,316	15845
33	state	11	0	3	204,092	15843
34	federal	11	0	3	1,783,168	15843
35	state	44	0	0	217,004	15842
36	federal	44	0	0	1,895,986	15842
37	state	11	0	0	36,747	15841
38	federal	11	0	0	321,062	15841

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 Cost* tab calculations automatically update the local costs table at the bottom of the *Local Costs* tab.

LRSS Receipts and Disbursements Worksheet			
RECEIPTS FOR ROAD AND STREET PURPOSES		DISBURSEMENTS FOR ROAD AND STREET PURPOSES	
ITEM	TOTAL RECEIPTS	ITEM	DISBURSEMENT AMOUNT
A. RECEIPTS FROM LOCAL SOURCES		A. LOCAL DISBURSEMENTS (Identify by footnote the application of private contributions)	
1. Special Assessments		1. Capital Projects - Construction, Expansion and Preservation	
a. Permanent Property Tax or Assessment	12,797,909	a. Right-of-way	49,444,556
b. Limited Duration Property Tax or Assessment	1,558,936	b. Project engineering	61,648,792
c. Traffic impact fees or system development charges	69,336,043	c. Construction	
d. Transportation Utility Fees	9,565,963	-1 New Facilities	31,867,666
e. Local Improvement Districts (or similar)	37,214,253	-2 Capacity Improvements	155,105,914
f. Urban Renewal District	4,656,268	-3 Bicycle and Pedestrian Paths	8,740,274
		-4 System Preservation	106,188,788
2. General Fund and Non-Dedicated City/County Fund Transfers	63,087,781	-5 System Enhancement	61,921,393
3. Local Option Road User Fees (Include only what you actually keep)		2. Operations and Maintenance	

Studded Tires

The *Studded Tire* tab contains the state and local studded tire-related expenditures.

The top right table on the *Studded Tire* tab contains the state studded tire costs from the 2005, 2007, 2009, and 2011 studies. Issue Paper 5 from the 2005 study explains the studded tire cost approach developed for that study. The 2005 HCAS studded tire costs have been updated in subsequent studies by adjusting the studded tire costs for inflation (the general increase in the cost of the preservation work) and the increase in studded tire damage, which is approximated using the basic-vehicle VMT growth rate.

Funding	Work Type	Facility Class	Dollars	2005	2007	2009
state	1	0	1,042,877	900,000	990,138	1,042,877
state	11	0	17,381,281	15,000,000	16,502,298	17,381,281
state	26	0	3,512,762	3,000,000	3,335,119	3,512,762
local-state	101	-2	114,716	18,900,000	20,827,555	21,936,920
local-state	111	-2	1,911,941			
local-state	126	-2	386,404			
				Speed-Adjusted Local to State Basic VMT or		
				11.00%		
				Preservation Inflation Rate		
				3%		

The inflation rate is a user-specified assumption in a yellow-shaded cell labeled *Preservation Inflation Rate*. Past studies have assumed a three percent inflation rate. The basic-vehicle VMT growth rate from the *VMT Growth* tab is automatically applied to the previous study's studded tire costs along with the inflation rate.

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 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. If the user chooses to update this assumption, the *VMT Master* tab containing the VMT by functional class and ownership by weight class can be used to update this assumption.

Gas and Diesel

The *Gas and Diesel* tab uses the VMT from the *Base VMT* tab and the *VMT Growth* tab rates 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. These estimates are then used to derive the percent of basic VMT by diesel-powered vehicles, an input in the *Revenues* tab.

	A	B	C	D	E	F	G
1	Gas and Diesel						
2							
3	VMT from Model	Gas	Diesel	Unknown	Total	Not Taxed	Taxed
4	Basic	617,135,911	215,497,962	2,254,589,594	34,207,245,548	308,292,795	33,898,952,
5	Non-Basic	169,318,508	397,108,738	33,374,611,675	2,821,016,840	2,094,773,265	726,243,
6	All	786,454,419	612,606,700	35,629,201,269	37,028,262,388	2,403,066,060	34,625,196,
7							
8							
9	Revenue Control	$ 425,589,239					
10							
11	Assumptions						
12	Percent of taxed gallons that are diesel			9.47%			
13	Percent of basic gallons that are diesel			6.75%			
14	Percent of RV gallons that are diesel			40.00%			
15	Percent of taxed gallons that are basic			96.00%	95.89%	Assuming twice the MPG for	
16							
17	Implied Gallons	Gas	Diesel	Total		Instructions	
18	Basic	1,587,447,860	114,909,094	1,702,356,954		1. This worksheet calculates	
19	Non-Basic	17,910,214	53,021,326	70,931,540		2. The Revenue Control is u	
20	All	1,605,358,073	167,930,420	1,773,288,494		Revenue Control is automati	
21						3. Adjust yellow highlighted	
22	Implied MPG	Gas	Diesel	Total			
23	Basic			19.91			
24	Non-Basic	18.12	7.58	10.24			
25	All			19.53			
26							
27	Implied Shares	Gas	Diesel	Total			
28	Basic	0.8952	0.0648	0.9600			
29	Non-Basic	0.0101	0.0299	0.0400			
30	All	0.9053	0.0947	1.0000			
31							
32	Percent of basic VMT by diesel-powered vehicles			0.0675			
33							

Below the VMT table is Revenue Control, which is average annual gas and diesel tax revenues. Gas tax revenues and diesel tax revenues from the *Revenues* tab are added and divided by two to calculate the average annual revenue. Revenue Control is divided by the gas/diesel tax rate per gallon to calculate the total implied gallons.

Percent of taxed gallons that are diesel, the first entry in the Assumptions table, is calculated from the gas and diesel tax revenues from the *Revenues* tab. Diesel tax revenues are divided by total gas and diesel tax revenues to derive the percent of fuel tax revenues from diesel fuel.

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.

The yellow-shaded assumptions are: percent of basic gallons that are diesel, percent of RV gallons that are diesel, and percent of taxed gallons that are basic. 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 should be entered as a percent; a reasonable value would be within the range of 5 to 8 percent.
- The percent of RV gallons that are diesel should be entered as a percent. A reasonable range for this assumption would be between 30 and 60 percent.
- The percent of taxed gallons that are basic is entered as a percent, and should be roughly equal to the taxed basic VMT divided by total taxed VMT plus total taxed non-basic VMT (assume basic vehicles have roughly twice the fuel efficiency of non-basic vehicles).

The ranges for each of these user-specified rates are only guidelines; the objective should be reasonable MPG estimates.

The percent of basic VMT by diesel-powered vehicles, the bottom line on the tab, adjusts as the implied shares for gas and diesel-powered vehicles changes. The percent of basic VMT by diesel-powered vehicles is referenced by the *Revenues* tab and is used to attribute fuel tax revenues.

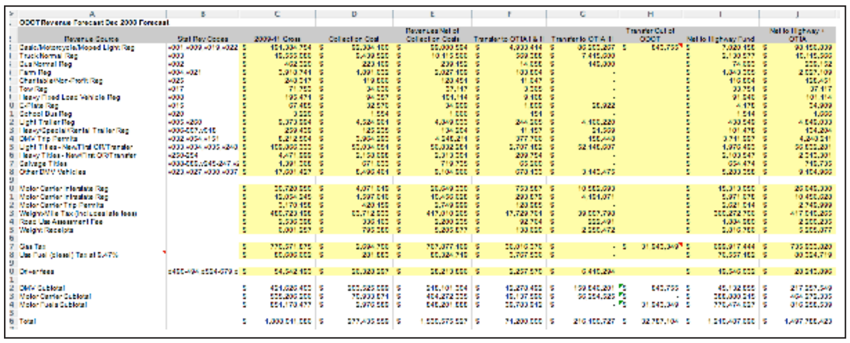
Bridge Splits

The *Bridge Splits* tab 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 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 can adjust the share for each bridge type and work type, such that the sum of the shares by bridge type equals one.

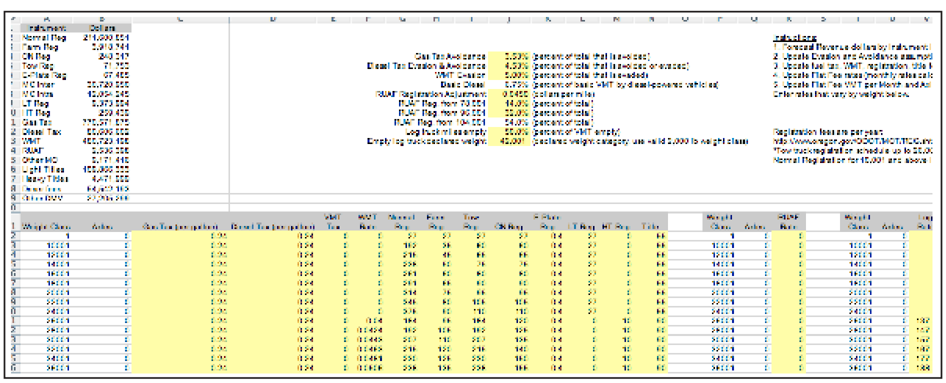
Bridge Type	Work Type	Share
0	60	0.6098
0	61	0.2878
0	62	0.0333
0	63	0.0691
0	64	0
1	60	0.6098
1	61	0.2878
1	62	0.0333
1	63	0.0691
1	64	0
2	60	0.6176
2	61	0.2909
2	62	0.0136
2	63	0.0779
2	64	0
3	60	0.4324
3	61	0.2213
3	62	0.0565
3	63	0.2898
3	64	0
4	60	0.7962
4	61	0.0752
4	62	0.0875
4	63	0.0411
4	64	0

Rev 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 *Rev 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 forecast into the yellow-shaded cells because the revenues by revenue sources will automatically calculate the revenue control totals in the top left of the *Revenues* tab.

Revenues



The *Revenues* tab contains three different sets of input used in the revenue attribution calculations: revenue control totals, evasion rates, and the revenue instrument rates (tax rates and fees).

The revenue control totals, at the top left of the *Revenues* tab, are updated by the data on the *Rev 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, while the other revenue instrument revenue totals are calculated using the revenue rates and VMT calculations. Driver Fees and Other DMV revenues are displayed on the *Revenues* tab but are not included in the HCAS model because revenue from these sources do not go into the State Highway Fund (i.e., the named range *RevenueTotals* should not include the last two cells of the revenue control input).

	A	B
1	Instrument	Dollars
2	Normal Reg	211,600,851
3	Farm Reg	3,918,741
4	CN Reg	248,317
5	Tow Reg	71,753
6	E-Plate Reg	67,485
7	MC Inter	30,720,950
8	MC Intra	12,054,245
9	LT Reg	9,373,994
10	HT Reg	259,439
11	Gas Tax	770,571,875
12	Diesel Tax	80,606,602
13	WMT	480,723,198
14	RUAF	2,536,398
15	Other MC	9,171,416
16	Light Titles	109,866,333
17	Heavy Titles	4,471,999
18	Driver fees	54,542,193
19	Other DMV	27,205,299

The evasion assumptions, located in the center of the top portion of the *Revenues* tab, are the user-specified assumptions for the gas, diesel, and WMT avoidance or evasion rates; the percent of basic VMT by diesel-fueled vehicles (calculated in the *Gas and Diesel* tab); the RUAF registration revenue allocation; and empty log truck miles and weight.

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 this assumption by entering a percentage in the yellow-shaded evasion cells.

Similarly, the WMT tax evasion rate is expressed as the percent of total WMT VMT that evades the WMT tax. The WMT evasion rate is applied to WMT vehicle class VMT to calculate WMT tax 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.

Gas Tax Avoidance	3.53%	(percent of total that is avoided)
Diesel Tax Evasion & Avoidance	4.53%	(percent of total that is avoided or evaded)
WMT Evasion	5.00%	(percent of total that is evaded)
Basic Diesel	6.75%	(percent of basic VMT by diesel-powered vehicles)
RUAF Registration Adjustment	0.0450	(dollars per mile)
RUAF Reg. from 78,001	14.0%	(percent of total)
RUAF Reg. from 96,001	32.0%	(percent of total)
RUAF Reg. from 104,001	54.0%	(percent of total)
Log truck miles empty	50.0%	(percent of VMT empty)
Empty log truck declared weight	42,001	(declared weight category, use valid 2,000 lb weight class)

The Basic Diesel assumption is not a yellow-shaded assumption because this cell is linked to the calculated value in the *Gas and Diesel* tab. 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.

RUAF vehicles are credited with a portion of the heavy vehicle registration revenues using the RUAF Reg assumptions. The first RUAF Reg assumption is the RUAF Reg 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 Reg assumptions allocate the RUAF registration revenue across three RUAF vehicle weight groups by specifying the portion of RUAF vehicles, which register at three different registration weight classes. Since the total of these three assumptions must equal 100 percent, the percent of total for RUAF Reg. from 104,001 is calculated as 100 minus the values specified in RUAF Reg. from 78,001 and RUAF Reg. from 96,001. RUAF Reg. from 78,001 and RUAF Reg. from 104,001 must be entered as percentages in the yellow-shaded cells.

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.

The tax and fee rates for the revenue instruments are located in the yellow-shaded cells at the bottom of the *Revenues* 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. Take the two-year registration fee and divide by two to annualize the registration fee. The Normal Reg is the passenger vehicle registration fee for basic vehicles and 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 ($2 registration fee divided by 5 years equals $0.40 per year).
- 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. The flat fee monthly VMT and axle shares are tabulated in the Flat Fee VMT Axle workbook.

Alt Rates

The *Alt Rates* tab is described in the Alternative Rate Analysis User Guide in Section 6.

MPG

The *MPG* tab contains the MPG assumptions by declared weight class and the adjusted MPG by weight class.

	A	B	C	D	E
1					
2					
3	Declared	MPG		Weight Class	Adjusted MPG
4	1	20.00		1	19.58
5	10,001	10.85		10,001	8.31
6	12,001	10.27		12,001	7.86
7	14,001	9.77		14,001	7.48
8	16,001	9.33		16,001	7.14
9	18,001	8.94		18,001	6.85
10	20,001	8.59		20,001	6.58
11	22,001	8.27		22,001	6.34
12	24,001	7.98		24,001	6.11
13	26,001	7.15		26,001	7.15
14	28,001	7.04		28,001	7.04
15	30,001	6.94		30,001	6.94
16	32,001	6.85		32,001	6.85
17	34,001	6.76		34,001	6.76
18	36,001	6.67		36,001	6.67
19	38,001	6.59		38,001	6.59
20	40,001	6.52		40,001	6.52
21	42,001	6.45		42,001	6.45
22	44,001	6.38		44,001	6.38

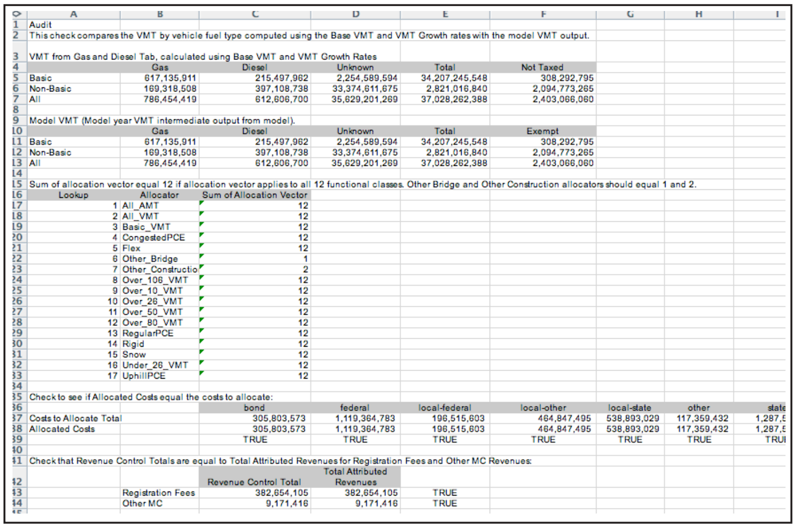
The assumed MPG values in the yellow-shaded cells were derived from a regression analysis of the Vehicle Inventory and Use Statistics (VIUS) 2002 data (U.S. Census Bureau). VIUS data collection was discontinued after 2002. The MPG assumptions by weight class can be updated when better information or 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. 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 sent back to Excel where it may be examined for reasonableness. 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.

Section 5: Recalculating the Model

To recalculate the model, go to the *Control* tab and click the "Recalculate" button. Make sure that the Excel workbook macros are enabled and that the HCASModule.py has been registered. See the Technical Documentation in Appendix E for instructions on how to register the HCASModule file.

Auditing



	A	B	C	D	E	F	G	H	I
1	Audit								
2	This check compares the VMT by vehicle fuel type computed using the Base VMT and VMT Growth rates with the model VMT output.								
3	VMT from Gas and Diesel Tab, calculated using Base VMT and VMT Growth Rates								
4		Gas	Diesel	Unknown	Total	Not Taxed			
5	Basic	617,135,911	215,497,962	2,254,589,594	34,207,245,548	308,292,795			
6	Non-Basic	169,318,508	397,108,738	33,374,611,675	2,821,016,840	2,094,773,265			
7	All	786,454,419	612,606,700	35,629,201,269	37,028,262,388	2,403,066,060			
8									
9	Model VMT (Model year VMT intermediate output from model).								
10		Gas	Diesel	Unknown	Total	Exempt			
11	Basic	617,135,911	215,497,962	2,254,589,594	34,207,245,548	308,292,795			
12	Non-Basic	169,318,508	397,108,738	33,374,611,675	2,821,016,840	2,094,773,265			
13	All	786,454,419	612,606,700	35,629,201,269	37,028,262,388	2,403,066,060			
14									
15	Sum of allocation vector equal 12 if allocation vector applies to all 12 functional classes. Other Bridge and Other Construction allocators should equal 1 and 2.								
16	Lookup	Allocator	Sum of Allocation Vector						
17	1	All_AMT	12						
18	2	All_VMT	12						
19	3	Basic_VMT	12						
20	4	CongestedPCE	12						
21	5	Flex	12						
22	6	Other_Bridge	1						
23	7	Other_Constructio	2						
24	8	Over_106_VMT	12						
25	9	Over_10_VMT	12						
26	10	Over_26_VMT	12						
27	11	Over_50_VMT	12						
28	12	Over_80_VMT	12						
29	13	RegularPCE	12						
30	14	Rigid	12						
31	15	Snow	12						
32	16	Under_26_VMT	12						
33	17	UphillPCE	12						
34									
35	Check to see if Allocated Costs equal the costs to allocate:								
36			bond	federal	local-federal	local-other	local-state	other	state
37	Costs to Allocate Total		305,803,573	1,119,364,783	196,515,603	464,847,495	538,893,029	117,359,432	1,287,5
38	Allocated Costs		305,803,573	1,119,364,783	196,515,603	464,847,495	538,893,029	117,359,432	1,287,5
39			TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUI
40									
41	Check that Revenue Control Totals are equal to Total Attributed Revenues for Registration Fees and Other MC Revenues:								
42			Revenue Control Total	Total Attributed Revenues					
43		Registration Fees	382,654,105	382,654,105	TRUE				
44		Other MC	9,171,416	9,171,416	TRUE				

Recalculating the model should take a few seconds. 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 recalculated, first review the model results to check that the VMT, cost allocation, and revenue attribution in the intermediate and results tabs are reasonable.

The *Audit* tab has been added to the HCAS Model to facilitate the auditing of the input and model output data for the VMT, allocation vectors, and costs. See the description of the *Audit* tab in the tab-by-tab explanation of the Model output tabs.

When auditing the model input and output, the *Audit* tab allows for rounding errors. For example, the costs to allocate and allocated costs should be within a few dollars of each other. A discrepancy equal to the magnitude of biennial project expenditures would indicate that some of the costs to allocate (input) were not allocated in the model calculations. In this case, the user should review the project cost, non-project costs, and local costs to see that funding, work types, functional system, and bridge types were correctly entered.

The following are general checks that can be performed to audit the model output:

- Check that the Model VMT and Master VMT are consistent. Total Model VMT by weight class should equal the Master VMT for facility class zero (the facility class for any functional system, any owner).
- 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.
- Check to see if any pavement factors are listed as missing by reviewing the missing_pavement_factors text file in the HCAS Model folder. If the

missing_pavement_factors 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 should equal their control totals from the *Revenues* tab.

Basic Troubleshooting

If nothing happens after clicking "Recalculate," or if the Excel Visual Basic Editor opens after clicking "Recalculate," check that Excel macros are enabled.

Invalid data or assumptions entered in input fields or a misspelled allocator can trigger an error, which will prevent the model from recalculating. Review all input data and make sure all named ranges in the HCAS Model workbook are properly defined and contain valid data.

Tab-by-Tab Explanation of Model Output

Recalculating the HCAS model will produce new output in the intermediate, results, and report exhibit tabs.

Intermediate results can be found in the following tabs: *Audit*, *Model VMT, VMT Master, Allocated Costs by SWT, Costs to Allocate by SWT, Allocated Costs, Attributed Revenues, and Allocation Vectors.* Additional detailed output can be found in the model output text files in the HCAS Model folder.

Audit

The *Audit* tab compares the model input and output for the VMT, cost allocation, allocation vectors, and revenue attribution for select revenue instruments. While the *Audit* tab is not a comprehensive validation of the model input and calculations, if the model data have been updated without any further code modifications, then the *Audit* tab will allow the user to check that the input data were processed and used in the model calculations correctly.

VMT Check The Gas and Diesel VMT calculated in the model workbook using the *Base VMT* and *VMT Growth* rates are compared to the same Gas and Diesel VMT table calculated from the output on the *Model VMT* tab.

VMT from the *VMT Master* tab and the *Model VMT* tab are compared in columns L through O to check that Model Year VMT totals by weight class are equal the VMT for all functional class/ownership in the *VMT Master* tab.

Allocation Vectors The allocation vectors should sum to 12 for allocators applied on all 12 functional systems and to another whole number if another type of allocator applied to a limited number of functional systems. Check that the allocation vectors sum to a whole number and make sense given the type of allocator.

Costs to Allocate and Allocated Cost Check Check that the summarized costs to allocate are equal to the allocated costs by comparing the costs by summary work types. A discrepancy (of more than a few dollars) will likely indicate a data input error on the *Project Costs* tab.

Revenue Control Total Check Check that the registration fees and Other MC revenues are equal to their revenue control totals. These are the only two revenue instruments set to their control totals.

Model VMT

The *Model VMT* tab contains the intermediate output of projected VMT in the forecast year by vehicle weight class and vehicle tax class. This table is analogous to the Base VMT table but for the model year. The VMT growth rates are applied to the Base VMT to produce the Model VMT output.

	A	B	C	D	E	F	G	H	I	J	K
1	Weight Class	Private Passenger	Gas Commercial 8-26	Diesel & Other Commercial 8-26	Gas Tow Trucks	Diesel & Other Tow Trucks	RUAF Vehicles	Flat Fee Vehicles Log	Flat Fee Vehicles S&G	Flat Fee Vehicles Chip	WMT Vehicles 26-80 Any Axle
2	WC	Cars	GasComm	DieselComm	GasTow	DieselTow	RUAF	FlatFeeLog	FlatFeeSG	FlatFeeChip	WMTA
3	1	33,374,611,675	0	0	2,418,651	5,208,261	0	0	0	0	0
4	10,001	29,659,399	41,879,109	37,064,092	825,656	1,710,287	0	0	0	0	0
5	12,001	19,522,178	14,101,681	20,366,182	432,486	1,887,214	0	0	0	0	0
6	14,001	61,832,463	18,659,826	43,346,942	1,002,582	3,479,550	0	0	0	0	0
7	16,001	39,237,009	6,332,651	22,132,824	353,853	2,103,457	0	0	0	0	0
8	18,001	35,585,775	6,049,569	21,189,217	353,853	2,850,479	0	0	0	0	0
9	20,001	0	2,096,904	6,018,115	176,926	452,145	0	0	0	0	0
10	22,001	16,714,948	3,994,603	9,215,894	98,292	1,297,459	0	0	0	0	0
11	24,001	20,265,269	14,258,949	67,740,490	825,656	11,716,452	0	0	0	0	0
12	26,001	6,221,125	0	0	0	0	0	0	0	0	2,373,938
13	28,001	6,319,438	0	0	0	0	0	0	19,714	0	5,027,595
14	30,001	23,210,736	0	0	0	0	0	0	0	0	13,219,461
15	32,001	0	0	0	0	0	0	0	0	0	27,567,960
16	34,001	0	0	0	0	0	0	0	0	0	4,957,281
17	36,001	0	0	0	0	0	0	0	0	0	2,260,910
18	38,001	0	0	0	0	0	0	0	0	0	4,635,717
19	40,001	0	0	0	0	0	0	0	0	0	4,230,827
20	42,001	0	0	0	0	0	0	0	0	0	2,571,774
21	44,001	0	0	0	0	0	0	0	3,087	0	26,627,285
22	46,001	0	0	0	0	0	0	0	45,313	0	19,693,213
23	48,001	0	0	0	0	0	0	0	218,297	5,575	24,126,417
24	50,001	0	0	0	0	0	0	0	26,889	0	15,513,993
25	52,001	0	0	0	0	0	0	0	20,513	0	27,139,365
26	54,001	0	0	0	0	0	0	0	166,419	18,826	36,703,938
27	56,001	0	0	0	0	0	0	0	20,662	0	10,030,671
28	58,001	0	0	0	0	0	0	0	48,293	0	8,967,996
29	60,001	0	0	0	0	0	0	0	0	0	2,712,255
30	62,001	0	0	0	0	0	0	0	4,128	0	3,270,874
31	64,001	0	0	0	0	0	0	0	0	0	15,381,421
32	66,001	0	0	0	0	0	0	0	0	0	3,008,960
33	68,001	0	0	0	0	0	0	0	0	0	8,317,334
34	70,001	0	0	0	0	0	0	0	0	0	8,861,328
35	72,001	0	0	0	0	0	0	0	0	0	2,146,141
36	74,001	0	0	0	0	0	0	0	0	0	7,511,572
37	76,001	0	0	0	0	0	0	53,015	24,508	0	1,049,846
38	78,001	0	0	0	0	0	0	53,842,710	591,461	10,615	1,136,427,413

VMT Master

The V*MT Master* tab contains the output of the model year VMT by roadway system. The model VMT calculations use the Base VMT, VMT Growth Rates, and VMT by FC input data to calculate VMT by roadway system and vehicle weight class. The *VMT Master* tab data are summarized in the *Equity* tab and *Alt Equity* tab and are also used in the report exhibit tabs.

	A	B	C	D
2	Functional Class	Weight Class	Axles	VMT
3	-2	1	0	13,576,412,995
4	-2	10,001	0	35,178,727
5	-2	12,001	0	23,144,785
6	-2	14,001	0	40,151,994
7	-2	16,001	0	21,371,882
8	-2	18,001	0	20,787,126
9	-2	20,001	0	4,576,611
10	-2	22,001	0	12,473,870
11	-2	24,001	0	47,740,828
12	-2	26,001	0	6,067,954
13	-2	28,001	0	7,314,948
14	-2	30,001	0	18,710,349
15	-2	32,001	0	11,858,724
16	-2	34,001	0	4,179,557
17	-2	36,001	0	2,017,005
18	-2	38,001	0	9,883,367
19	-2	40,001	0	1,419,638
20	-2	42,001	0	1,385,642
21	-2	44,001	0	9,359,897
22	-2	46,001	0	7,026,383
23	-2	48,001	0	8,381,654
24	-2	50,001	0	5,107,163
25	-2	52,001	0	8,352,498
26	-2	54,001	0	11,149,119
27	-2	56,001	0	3,310,690
28	-2	58,001	0	2,526,183
29	-2	60,001	0	816,299
30	-2	62,001	0	987,178
31	-2	64,001	0	4,397,450
32	-2	66,001	0	824,585
33	-2	68,001	0	2,044,894
34	-2	70,001	0	1,467,183
35	-2	72,001	0	284,516
36	-2	74,001	0	1,083,929
37	-2	76,001	0	109,781
38	-2	78,001	0	132,163,294

Costs to Allocate by Summary Work Type (SWT)

The *Costs to Allocate by SWT* tab 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 to produce this summary table, no other calculations are performed on the input data to produce the *Costs to Allocate by SWT*. 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 the Final Report Chapter 4 exhibits.

	A	B	C	D	E	F	G	H	I	J
3	Summary Work Type Name	summaryWorkType	bond	federal	local-federal	local-other	local-state	other	state	Total
4	Admin	1	-	72,717,537	38,572,168	91,240,469	105,774,159	-	648,146,237	95645057
5	Bike and Pedestrian	2	60,497	41,095,174	2,315,713	5,477,699	6,350,241	12,008,574	11,420,096	78727992
6	Bridge-bridge and interchange	3	50,138,041	235,085,603	3,596,401	8,507,100	9,862,196	17,318,050	38,774,852	36326224
7	Bridge-bridge maintenance	4	-	18,639	-	-	-	-	2,542	21180
8	Fish	5	14,526	10,567,545	-	-	-	924	943,669	11526663
9	Hwy Planning	6	-	8,410,590	-	-	-	204,457	8,399,075	170141
10	Hwy Safety	7	-	13,983,226	-	-	-	566,190	2,576,941	171283
11	Maintenance	8	-	15,124,066	3,497,477	8,273,102	9,590,924	122,663	313,609,196	35021742
12	Maintenance-bridge maintenance	9	-	11,097,258	-	-	-	5,160,632	14,971,363	312292
13	Maintenance-other pavement	10	-	13,081,633	-	-	-	-	94,976	131760
14	Maintenance-pavement maintenance	11	880,867	29,490,073	59,066,173	139,717,078	161,587,244	-	65,782,504	45630483
15	Modernization	12	1,843,655	132,080,337	31,291,515	74,018,401	85,808,858	24,366,095	19,392,075	36880099
16	Modernization-new pavement	13	1,708,298	32,939,121	17,504,359	41,405,655	48,001,160	29,954,003	10,638,494	18215108
17	Modernization-other pavement	14	479,603	544,116	-	-	-	-	55,889	1079668.
18	Modernization-pavement and shoulder	15	1,636,492	66,227,969	-	-	-	23,570,456	12,851,576	10428049
19	Multimodal	16	-	-	-	-	-	-	-	
20	PE	17	2,017,611	93,856,167	6,957,327	16,457,197	18,963,947	-	33,985,237	17223748
21	Preservation	18	-	-	-	-	-	-	-	
22	Preservation-other pavement	19	-	-	-	-	2,413,061	-	21,936,920	24349981
23	Preservation-pavement and shoulder re	20	2,563,222	241,135,244	28,134,442	66,550,567	75,239,463	2,981,239	31,395,955	44800013
24	Prior Alloc'td Bonds	21	235,581,665	-	-	-	-	-	-	2355816
25	ROW	22	9,099,037	47,471,883	5,580,027	13,199,266	15,301,777	-	17,717,009	10836899
26	Transit	23	-	332,688	-	-	-	534,650	1,463	8688
27	Unknown	24	0	54119916.03	0	0	0	571500.3385	34811389.63	895026
30	Costs to Allocate Total		$ 305,803,573	$ 1,119,364,783	$ 196,515,603	$ 464,847,495	$ 538,893,029	$ 117,359,432	$ 1,287,507,458	$ 4,030,291,3
33	Annual Expenditures (thousands)		$152,902	$559,682	$98,258	$232,424	$269,447	$58,680	$643,754	$2,015,1

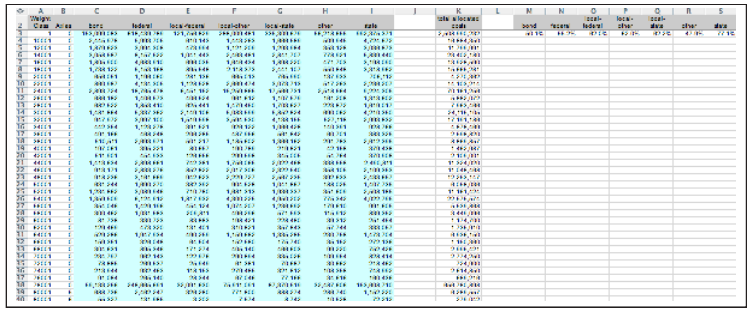
Allocated Costs by SWT

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

	A	B	C	D	E	F	G	H	I	J	K
2				Summary Weight Class							
3	Summary Work Type Name	funding	summaryWorkType	1	10001	26001	78001	80001	104001	105501	Total
4	Other	bond	1	0	0	0	0	0	0	0	
5	Other	bond	2	49645.45508	1554.331437	884.9591479	6317.339321	1145.663982	940.5450831	8.937185454	60497
6	Bridge	bond	3	20782577.08	3068559.205	1998969.654	8717131.771	8001934.691	7483325.217	85542.94991	5013
7	Bridge	bond	4	0	0	0	0	0	0	0	
8	Other	bond	5	13084.60792	308.8456417	176.7001207	678.0411258	142.9072704	133.095864	1.497244288	1452
9	Other	bond	6	0	0	0	0	0	0	0	
10	Other	bond	7	0	0	0	0	0	0	0	
11	Maintenance	bond	8	0	0	0	0	0	0	0	
12	Maintenance	bond	9	0	0	0	0	0	0	0	
13	Maintenance	bond	10	0	0	0	0	0	0	0	
14	Maintenance	bond	11	202904.6595	35459.59113	39652.35156	272850.1022	60921.24408	44706.96841	4371.671101	6608
15	Modernization	bond	12	1454987.88	52512.44268	47137.54182	197875.2048	43162.03876	47468.75701	511.2755035	1843
16	Modernization	bond	13	247357.4323	106871.6483	125135.2736	875610.0902	195765.291	143299.4656	14259.29453	1708
17	Modernization	bond	14	278681.3422	16665.13794	17931.06836	106287.2157	20684.71067	38539.25517	874.0895703	4796
18	Modernization	bond	15	512746.489	106893.2665	105229.9183	651429.3717	135957.7569	112058.4653	12176.78337	1636
19	Other	bond	16	0	0	0	0	0	0	0	
20	Other	bond	17	1267873.888	81961.91776	72629.42052	377320.8453	111764.4452	101691.5527	4368.627602	2017
21	Preservation	bond	18	0	0	0	0	0	0	0	
22	Preservation	bond	19	0	0	0	0	0	0	0	
23	Preservation	bond	20	777160.6706	134788.7865	158095.727	1072465.125	231667.9773	172731.0066	16312.5874	2563
24	Prior	bond	21	121844451.3	11359982.96	12003127.78	45128841.5	21061790.06	23660453.21	523018.1986	23558
25	Other	bond	22	5667612.39	373415.2744	330911.2901	1726449.785	514061.7469	466291.6355	20294.86876	909
26	Other	bond	23	0	0	0	0	0	0	0	
27	Other	bond	24	0	0	0	0	0	0	0	
28	Other	federal	1	60484083.8	1427650.396	1885924.318	6269293.431	1348505.796	1286447.132	15632.09058	7271
29	Other	federal	2	37206797.05	860631.1167	490630.6557	1791825.114	381475.135	359685.1934	4130.23409	4109
30	Bridge	federal	3	106204958.7	16528917.83	10743722.5	37903057.5	31809418.14	31484708.8	390819.2272	23506
31	Bridge	federal	4	16789.64997	396.2984791	226.7345873	870.0354826	183.372942	170.7833343	1.921204492	1863
32	Other	federal	5	9534195.057	222583.4156	130488.5694	481004.2713	101834.7243	96357.61746	1081.601563	1056

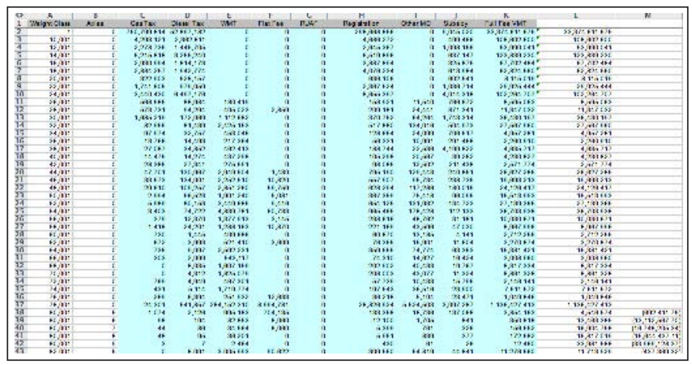
Allocated Costs tab and in the *Allocated Cost* output text files. Whereas the *Allocated Costs* tab contains the allocated costs for every weight class, the *Allocated Costs by SWT* is a summary table for the purpose of creating the exhibits for Chapter 5 of the Final Report.

Allocated Costs



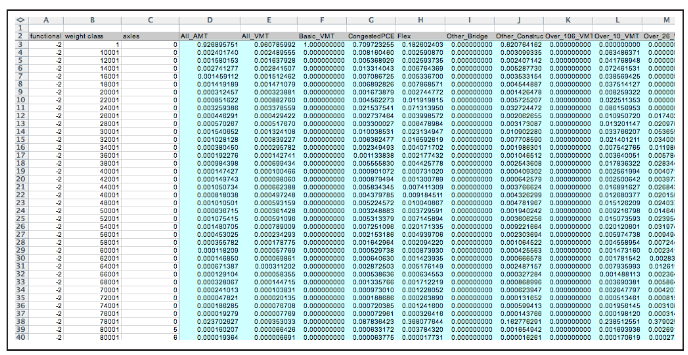
The *Allocated Costs* tab displays the costs allocated in the model for each funding source to each weight class and axle class. This tab does not contain any information on the work types of the allocated costs. The output on the *Allocated Costs* tab is used in the *Equity* tab and in the *Summary* tab 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 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.

Allocation Vectors



The *Allocation Vectors* tab displays the Allocation Vectors used in the model. This output tab was added to the model for auditing purposes. Each allocation vector should sum to twelve if the allocator applies to all twelve facility classes.

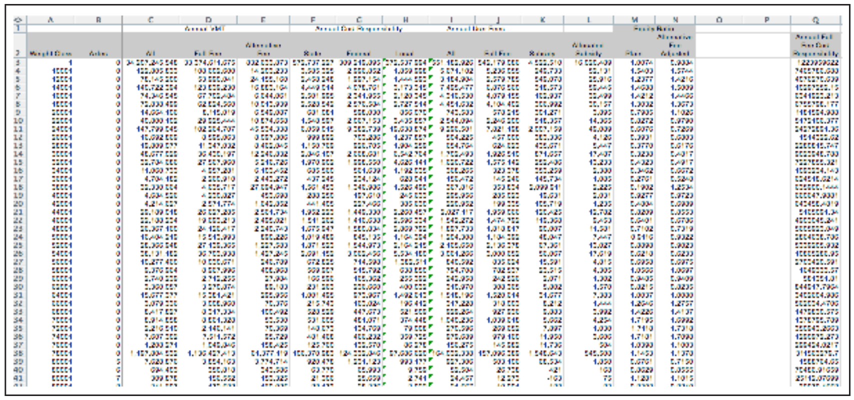
Results tabs

The *Equity* and *Summary* tabs summarize the intermediate output tabs, displaying the final results and equity ratios. These tabs reference the intermediate output tabs and do not require any user input.

Equity

The *Equity* tab contains the Annual VMT, Annual Cost Responsibility, Annual User Fees, and Subsidy 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 Allocated Subsidy is the total from the Subsidy column distributed over the vehicle weight classes using the vehicle weight class share of full-fee VMT. The "Plain" Equity Ratio is calculated as the ratio of the cost responsibility share to the user fee share for all vehicles, whereas the Adjusted-Equity Ratio is the ratio of the share of full-fee cost responsibility to the full-fee user fee share.

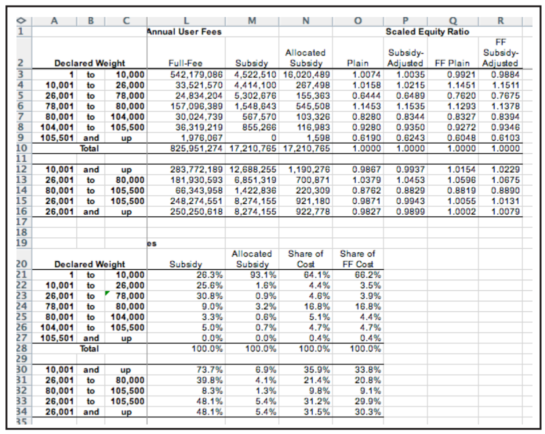


Summary

The *Summary* tab summarizes the model results for the major vehicle weight classes. The Annual VMT, Annual Cost Responsibility, and Annual User Fees are linked to the *Equity* tab. The VMT, Cost Responsibility and User Fee shares and the equity ratios are also located on the *Summary* tab.

The summary worksheet calculates the different Scaled Equity Ratios as follows:

- Subsidy-Adjusted Scaled Equity Ratio: Ratio of the share of All User Fees to the share of All Cost Responsibility plus the Allocated Subsidy
- Full-Fee Plain Scaled Equity Ratio (FF Plain): Ratio of the share of Full-Fee User Fees to the share of Full-Fee Cost Responsibility
- Full-Fee Subsidy-Adjusted Equity Ratio (FF Subsidy-Adjusted): Ratio of the share of Full-Fee User Fees to the share of Full-Fee Cost Responsibility plus the Allocated Subsidy



	A	B	C	L	M	N	O	P	Q	R
1				Annual User Fees				Scaled Equity Ratio		
2	Declared Weight			Full-Fee	Subsidy	Allocated Subsidy	Plain	Subsidy-Adjusted	FF Plain	FF Subsidy-Adjusted
3	1	to	10,000	542,179,086	4,522,510	16,020,489	1.0074	1.0035	0.9921	0.9884
4	10,001	to	26,000	33,521,570	4,414,100	267,498	1.0158	1.0215	1.1451	1.1511
5	26,001	to	78,000	24,834,204	5,302,676	155,363	0.6444	0.6489	0.7620	0.7675
6	78,001	to	80,000	157,096,389	1,548,643	545,508	1.1453	1.1535	1.1293	1.1378
7	80,001	to	104,000	30,024,739	567,570	103,326	0.8280	0.8344	0.8327	0.8394
8	104,001	to	105,500	36,319,219	855,266	116,983	0.9280	0.9350	0.9272	0.9346
9	105,501	and	up	1,976,067	0	1,598	0.6190	0.6243	0.6048	0.6103
10	Total			825,951,274	17,210,765	17,210,765	1.0000	1.0000	1.0000	1.0000
11										
12	10,001	and	up	283,772,189	12,688,255	1,190,276	0.9867	0.9937	1.0154	1.0229
13	26,001	to	80,000	181,930,593	6,851,319	700,871	1.0379	1.0453	1.0596	1.0675
14	80,001	to	105,500	66,343,958	1,422,836	220,309	0.8762	0.8829	0.8819	0.8890
15	26,001	to	105,500	248,274,551	8,274,155	921,180	0.9871	0.9943	1.0055	1.0131
16	26,001	and	up	250,250,618	8,274,155	922,778	0.9827	0.9899	1.0002	1.0079
17										
18										
19				es						
20	Declared Weight			Subsidy	Allocated Subsidy	Share of Cost	Share of FF Cost			
21	1	to	10,000	26.3%	93.1%	64.1%	66.2%			
22	10,001	to	26,000	25.6%	1.6%	4.4%	3.5%			
23	26,001	to	78,000	30.8%	0.9%	4.6%	3.9%			
24	78,001	to	80,000	9.0%	3.2%	16.8%	16.8%			
25	80,001	to	104,000	3.3%	0.6%	5.1%	4.4%			
26	104,001	to	105,500	5.0%	0.7%	4.7%	4.7%			
27	105,501	and	up	0.0%	0.0%	0.4%	0.4%			
28	Total			100.0%	100.0%	100.0%	100.0%			
29										
30	10,001	and	up	73.7%	6.9%	35.9%	33.8%			
31	26,001	to	80,000	39.8%	4.1%	21.4%	20.8%			
32	80,001	to	105,500	8.3%	1.3%	9.8%	9.1%			
33	26,001	to	105,500	48.1%	5.4%	31.2%	29.9%			
34	26,001	and	up	48.1%	5.4%	31.5%	30.3%			

Report Exhibits

The exhibit tabs are the tables that are typically included in the HCAS Final Report. The report exhibit tabs in the model workbook reflect the exhibit number in the 2011 HCAS Report. In the tables, the 2011 values are linked to the current model tabs, while previous study numbers are hard-pasted values in the tables.

To update the tables for a future biennial study, change the titles and column headings as appropriate to reflect the new study years. For exhibits displaying past study results, insert new columns for the 2011 HCAS results into the tables to the left of the cells with links to the current model tab results if the table shows previous study results. Make sure to preserve the formulas and links to the other tabs. Copy and paste the 2011 results in the newly inserted columns. Tables where only the current study results are displayed are automatically updated.

4-1 Exhibit 4-1: Current and Forecasted VMT by Weight Group

This table shows the VMT for the base year and the forecast year for each weight group (the major grouping of weight classes). The cell values for the top portion of this table are linked to the *Base VMT* tab, the bottom portion of the table are linked to the *Summary* results tab. This table is automatically updated.

4-2 Exhibit 4-2: Projected 2012 VMT by Road System (millions of miles)

This table shows the forecast year VMT by road system for light and heavy vehicles and the percent of total miles for light and heavy vehicles by road system. The top portion of the table is linked to the *VMT Master* tab and is automatically updated. VMT for city and county roads must be copied from the VMT Master output text file and pasted into the table (divide by 1,000,000 so that all table values are in millions of miles).

4-3 Exhibit 4-3: Distribution of Projected 2012 VMT by Road System

This table shows the percent of projected VMT by roadway system. This table is automatically updated using the model results in Exhibit 4-2.

4-4 Exhibit 4-4: Comparison of Forecast VMT Used in OR HCASs: 1999, 2001, 2003, 2005, 2007, 2009, and 2011 (billions of miles)

This table compares the VMT forecast from previous studies to the current study. The VMT from the previous studies are pasted into the table. The current study VMT are linked to the *Model VMT* tab and are automatically updated when the model is recalculated.

4-5 Exhibit 4-5: Average Annual Expenditures by Category and Funding Source (thousands of dollars)

This table shows the annual expenditures over the biennium by summary work type and funding source. This table is linked to the *Costs to Allocate by SWT* tab.

4-6 Exhibit 4-6: Revenue Forecasts by Tax/Fee Type (thousands of dollars), Average Annual Amounts for 2011-2013 Biennium

This table displays the total revenue attributed by major revenue instrument. This table is linked to data in the *Revenues* and *Attributed Revenues* tabs.

4-7 Exhibit 4-7: Comparison of Forecast Revenue (millions of dollars) Used in OR HCASs: 1999, 2001, 2003, 2005, 2007, 2009, and 2011

The previous study revenue forecasts are entered into the table and the current study revenue is linked to Exhibit 4-6.

5-1 Exhibit 5-1: Average Annual Cost Responsibility by Expenditure Category and Weight Class (thousands of dollars)

This table shows the average annual cost responsibility by summary work type and vehicle weight class. This table is linked to Exhibit 5-4.

5-2 Exhibit 5-2: Sources and Expenditures of Funds (thousands of annual dollars)

This table compares the costs to allocate and allocated costs by their funding source. The top portion of the table is linked to the *Costs to Allocate* tab and the bottom portion of the table is linked to the *Allocated Costs by SWT* tab.

5-3 Exhibit 5-3: Expenditure Allocation Results for Weight Groups by Funding Source (thousands of dollars)

This table shows the cost allocation results using the data in Exhibits 5-4, 5-5, and 5-6.

5-4 Exhibit 5-4: Average Annual Cost Responsibility, State Highway Fund Detail (thousands of dollars)

This table displays the Allocated Costs by summary work type (SWT) for state-funded projects.

5-5 Exhibit 5-5: Average Annual Cost Responsibility, Federal Detail (thousands of dollars)

This table displays the Allocated Costs by SWT for federally-funded projects.

5-6 Exhibit 5-6: Average Annual Cost Responsibility, Local Government Detail (thousands of dollars)

This table displays the Allocated Costs by SWT for locally-funded projects.

5-7 Exhibit 5-7: Average Annual Cost Responsibility, Bond Detail (thousands of dollars)

This table displays the Allocated Costs by SWT for bond-funded projects and is automatically updated. This table displays both current bond expenditures total and the prior bond expenditures allocated in the current study.

5-8 Exhibit 5-8: Comparison of Pavement Responsibility Results From 2009 and 2011 OR HCASs (thousands of annual dollars)

This table compares the current and previous study pavement expenditures for basic and heavy vehicle classes using the *Allocated Costs by SWT* tab data and is automatically updated.

5-9 Exhibit 5-9: Comparison of Bridge and Interchange Responsibility Results from 2009 and 2011 OR HCASs (thousands of dollars)

Exhibit 5-9 displays the summarized bridge and interchange project costs. This table uses data from the *Allocated Costs by SWT* tab and is automatically updated.

5-10 Exhibit 5-10: Average Annual Cost Responsibility by Weight Group with Prior Allocated Expenditures (thousands of dollars)

Exhibit 5-10 displays the allocation cost responsibility by summary weight group, including the prior allocated bond-financed expenditures. This table uses data from the Exhibit 5-10 and is automatically updated.

5-11 Exhibit 5-11: Cost Responsibility Distributions by Weight Group-Comparison Between 2009 and 2011 OR HCASs

Exhibit 5-11 compares the cost responsibility shares by summary weight group for the 2009 and 2011 studies. The 2009 cost shares must be pasted in from the prior year study. The 2011 Study cost responsibility shares are automatically updated from Exhibit 5-1.

5-12 Exhibit 5-12: Average Annual User-Fee Revenue by Tax Instrument and Weight Class (thousands of dollars)

Exhibit 5-12 shows the average annual revenue collection by tax instrument. This Exhibit is automatically updated from data in the *Attributed Revenues* tab.

5-13 Exhibit 5-13: Revenue Attribution Distributions by Weight Group-Comparison Between 2009 and 2011 OR HCASs

Exhibit 5-13 compares the attributed revenue shares from the 2009 Study and 2011 Study for each summary weight class. The 2009 Study attributed revenue shares should be copied and pasted from the 2009 Study. The 2011 Study attributed revenue shares are automatically updated from Exhibit 5-12.

6-1 Exhibit 6-1: Comparison of Average Annual Cost Responsibility and User Fees Paid by Full-Fee-Paying Vehicles by Declared Weight Class (thousands)

Exhibit 6-1 is the results summary table in the final HCAS report that displays the model VMT, cost responsibility, and revenue attribution results by major weight class groups. Exhibit 6-1 has commonly been used as a handout for presenting the model results since the equity ratio results are summarized for the major vehicle classes. Exhibit 6-1 is linked to the *Summary* tab and is automatically updated.

6-2 Exhibit 6-2: Comparison of Equity Ratios from the 1999, 2001, 2003, 2005, 2007, 2009, and 2011 Oregon Highway Cost Allocation Studies

Exhibit 6-2 compares the equity ratios from the 1999-2011 HCAS studies. The previous year equity ratios are hard-pasted into the table and the right-most column is linked to tab *6-1*. This table updates the current model results automatically.

6-3 Exhibit 6-3: Detailed Comparison of Average Annual Cost Responsibility and User Fees Paid by Full-Fee-Paying Vehicles by Declared Weight Class (Thousands)

Exhibit 6-3 is similar to the Equity tab containing the summarized VMT, cost allocation, revenue attribution and equity ratios for each weight class. This table updates automatically.

Output Text Files

Running the model generates several output text (.txt) files. It is important to keep the bond allocation output file in the HCAS Model folder because this file becomes an input file for future studies. Running the 2011 model generates the bond file for 2011-2013 that will be used in the 2013 HCAS study, along with the prior bond files from the previous three studies.

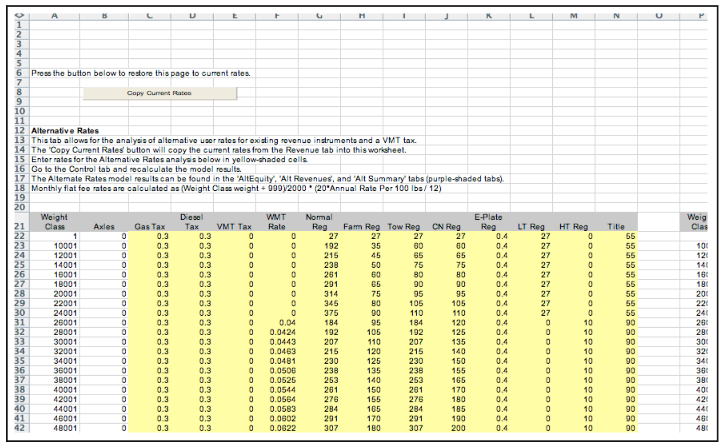
AllocatedCosts text files

The following allocated costs text files are generated with each model run: allocatedCosts_bond, allocatedCosts_federal, allocatedCosts_state, allocatedCosts_local-federal, allocatedCosts_local-state, allocatedCosts_local-other, and allocatedCosts_other

For each funding source, the text file contains allocated costs by work type for each vehicle weight and axle class. The size of these files requires that output text files be generated instead of including this disaggregated intermediate output as tabs in the model. Since there are just over 100 different weight and axle classes and more than 100 work types, each of these seven text files could contain up to roughly 10,000 records.

The format of the allocatedCosts text files is the same for all funding sources. The columns in the files are: funding, work type, weight class (WC), axles, and dollars.

Since allocated costs by funding source are summarized in the model intermediate output tab *Allocated Costs by SWT*, the allocatedCosts text output files are only required when the user/analyst is interested in looking at allocated costs for a particular work type or specific weight and axle class.


Press the button below to restore this page to current rates.

Copy Current Rates

Alternative Rates
This tab allows for the analysis of alternative user rates for existing revenue instruments and a VMT tax.
The 'Copy Current Rates' button will copy the current rates from the Revenue tab into this worksheet.
Enter rates for the Alternative Rates analysis below in yellow-shaded cells.
Go to the Control tab and recalculate the model results.
The Alternate Rates model results can be found in the 'AltEquity', 'Alt Revenues', and 'Alt Summary' tabs (purple-shaded tabs).
Monthly flat fee rates are calculated as (Weight Class weight + 999)/2000 * (20*Annual Rate Per 100 lbs / 12)

Weight Class	Axles	Gas Tax	Diesel Tax	VMT Tax	WMT Rate	Normal Reg	Farm Reg	Tow Reg	CN Reg	E-Plate Reg	LT Reg	HT Reg	Title
1	0	0.3	0.3	0	0	27	27	27	27	0.4	27	0	55
10001	0	0.3	0.3	0	0	192	35	60	60	0.4	27	0	55
12001	0	0.3	0.3	0	0	215	45	65	65	0.4	27	0	55
14001	0	0.3	0.3	0	0	238	50	75	75	0.4	27	0	55
16001	0	0.3	0.3	0	0	261	60	80	80	0.4	27	0	55
18001	0	0.3	0.3	0	0	291	65	90	90	0.4	27	0	55
20001	0	0.3	0.3	0	0	314	75	95	95	0.4	27	0	55
22001	0	0.3	0.3	0	0	345	80	105	105	0.4	27	0	55
24001	0	0.3	0.3	0	0	375	90	110	110	0.4	27	0	55
26001	0	0.3	0.3	0	0.04	184	95	184	120	0.4	0	10	90
28001	0	0.3	0.3	0	0.0424	192	105	192	125	0.4	0	10	90
30001	0	0.3	0.3	0	0.0443	207	110	207	135	0.4	0	10	90
32001	0	0.3	0.3	0	0.0463	215	120	215	140	0.4	0	10	90
34001	0	0.3	0.3	0	0.0481	230	125	230	150	0.4	0	10	90
36001	0	0.3	0.3	0	0.0506	238	135	238	155	0.4	0	10	90
38001	0	0.3	0.3	0	0.0525	253	140	253	165	0.4	0	10	90
40001	0	0.3	0.3	0	0.0544	261	150	261	170	0.4	0	10	90
42001	0	0.3	0.3	0	0.0564	276	155	276	180	0.4	0	10	90
44001	0	0.3	0.3	0	0.0583	284	165	284	185	0.4	0	10	90
46001	0	0.3	0.3	0	0.0602	291	170	291	190	0.4	0	10	90
48001	0	0.3	0.3	0	0.0622	307	180	307	200	0.4	0	10	90

Bonds2011-2013

Bond expenditures allocated during the 2011-2013 study.

DeclaredpaveFactors

The declaredpaveFactors file contains the pavement factors by declared operating weight.

Flat_fee_report

Flat_fee_report contains a summary of the flat fee revenues and as-if revenues for each flat fee commodity by weight class and axle class.

Missing_pavement_factors

Missing_pavement_factors 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

SubsidiesbyVehClass is an output file that contains the calculated subsidies by weight class and axle class.

VMTMaster

The VMTMaster text 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 text file is used to report the VMT by county and city ownership in Exhibit 4-2.

Section 6: HCAS User Guide for Policy Analysis of Alternative Rates

The HCAS model includes the option to analyze changes in revenue instrument taxes or fees. Alternative Rates is an optional analysis; if alternative rates have not been specified in the model, the user should ignore the alternative rate analysis output tabs.

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 pressing the "Recalculate" button. In the model calculations, the program calibrates the model to the rates and control totals in the *Revenues* tab, and then evaluates the effect of the modified rates specified by the user in the *Alt Rates* tab. The model reports the output from the current rates and alternative rate analyses separately.

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:

1. Update the current rates in the *Alt Rates* tab by pressing the "Copy Current Rates" button.
2. Enter the alternative rates in the *Alt Rates* tab.
3. Run the model using the newly specified alternative rates. Go to the *Control* tab and click the "Recalculate" button.
4. View the alternative rate results on the *Alt Revenues, Alt Equity,* and *Alt Summary* tabs.

The next section provides a tab-by-tab explanation of the alternative rate analysis tabs, followed by a detailed description of the revenue instruments and three alternative rate case studies to illustrate the alternative rate analysis.

Alt Rates Tab

The *Alt Rates* tab 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. These rates are in the yellow-shaded tables below the "Copy Current Rates" button. The "Copy Current Rates" button runs an Excel macro, which will copy the revenue instrument tax rates from the *Revenues* tab into the *Alt Rates* tab.

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.

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 [e-plate]): 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 Motor Carrier Transportation Division 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 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 *Revenues* tab into the *Alt Rates* tab and then modified by the user. The tax rates and fees are:

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 then 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 *Revenues* 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 (basic vehicles accounted for 80 percent of gasoline VMT in the 2011 HCAS). 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 (non-basic vehicles accounted for just over 60 percent of diesel VMT in the 2011 HCAS). 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 2011, no VMT tax exists in Oregon, however the VMT tax is a potential future revenue instrument and the HCAS 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).

The VMT tax revenues are calculated by applying the VMT tax rates to the gas VMT 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 Tax): dollars per mile

The WMT rate 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 rate 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 rate structure will affect the equity ratios for individual weight classes within the heavy vehicle group.

Vehicle Registration Fees: dollars per year

The Oregon Department of Motor Vehicles (DMV) registers most vehicles, with the exception of heavy vehicles (over 26,000 pounds), which must register with the Motor Carrier Transportation Division (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 *Revenues* and *Alt Revenues* 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 *Revenues* 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 Moter 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 2011 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 2011 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 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 flat fee paid by 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).

Alt Rate Output Tabs

The alternative rate analysis results are displayed in three purple output tabs: *Alt Equity, Alt Revenues,* and *Alt Summary*.

Alt Equity

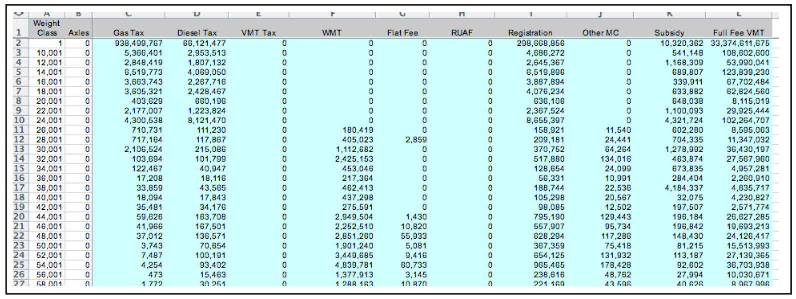
The *Alt Equity* tab displays the Annual VMT, Annual Cost Responsibility, Annual User Fees,

		Annual VMT			Annual Cost Responsibility			Annual User Fees				Scaled Equity Ratio		
Weight Class	Axles	All	Full-Fee	Alternative Fee	State	Federal	Local	All	Full-Fee	Subsidy	Allocated Subsidy	Plain	Subsidy-Adjusted	Full-Fee Annual Cost Responsibility
1	0	34,207,245,548	33,374,611,675	832,633,873	572,737,227	309,219,895	372,537,994	651,645,050	640,818,025	5,160,181	16,256,017	1.0590	1.0386	1,223,959,622
10001	0	122,805,833	108,602,600	14,203,233	3,585,325	2,996,852	1,859,998	6,503,093	5,990,252	270,574	52,898	1.5704	1.6014	7,465,787
12001	0	78,145,200	53,990,041	24,155,160	2,458,248	1,997,154	1,444,593	3,650,459	2,925,668	584,154	26,297	1.2614	1.4334	4,076,271
14001	0	140,722,394	123,839,230	16,883,164	4,449,014	4,078,761	3,173,315	8,554,359	7,831,574	344,903	60,319	1.4904	1.5198	10,297,252
16001	0	74,346,545	67,702,484	6,644,061	2,501,995	2,341,955	2,120,345	4,909,676	4,625,685	169,955	32,976	1.4372	1.4585	6,341,923
18001	0	72,838,499	62,824,560	10,013,939	2,528,542	2,576,584	2,727,514	5,055,011	4,633,409	316,941	30,600	1.3157	1.3723	6,755,798
20001	0	14,664,106	8,115,019	6,549,087	681,081	598,030	856,070	849,966	649,675	324,019	3,953	0.8116	1.1015	1,181,595
22001	0	40,800,102	29,925,444	10,874,658	1,548,597	2,067,153	3,435,857	2,884,177	2,518,883	550,047	14,576	0.8338	0.9761	5,172,106
24001	0	147,799,045	102,264,707	45,534,338	6,059,015	9,382,739	19,638,874	10,538,702	8,787,047	2,160,862	49,811	0.6125	0.7261	24,272,891
26001	0	16,692,869	8,595,063	8,097,806	999,892	703,286	1,237,857	586,421	457,000	301,140	4,186	0.4065	0.6049	1,514,323
28001	0	19,809,077	11,347,032	8,462,045	1,150,769	926,705	1,904,259	738,267	624,623	352,168	5,527	0.3780	0.5491	2,280,816
30001	0	48,677,029	36,430,197	12,246,832	2,846,107	2,668,681	6,542,764	1,934,654	1,926,510	639,496	17,744	0.3271	0.4283	9,023,949
32001	0	32,784,686	27,567,960	5,216,726	1,970,902	1,998,550	4,626,141	1,641,271	1,575,142	231,937	13,428	0.3893	0.4372	7,227,855
34001	0	11,060,733	4,957,281	6,103,452	685,560	561,639	1,192,035	384,606	323,378	336,917	2,415	0.3215	0.5932	1,093,234
36001	0	4,704,182	2,260,910	2,443,272	437,245	234,124	628,041	160,005	145,246	142,202	1,101	0.2510	0.4666	624,519
38001	0	32,330,664	4,635,717	27,694,947	1,561,453	1,346,986	1,526,490	375,558	353,834	2,092,169	2,258	0.1726	1.1145	635,900
40001	0	4,684,526	4,230,827	453,698	288,250	197,610	245,633	299,550	285,023	16,038	2,061	0.8349	0.8645	660,648
42001	0	4,214,627	2,571,774	1,642,852	441,405	227,466	385,630	227,918	199,335	98,753	1,253	0.4406	0.6215	643,458
44001	0	29,189,018	26,627,285	2,561,734	1,952,223	1,449,330	2,260,457	2,049,451	1,959,066	98,092	12,970	0.7379	0.7605	5,165,091
46001	0	22,188,234	19,693,213	2,495,021	1,511,262	1,416,638	2,596,334	1,563,219	1,474,792	98,421	9,592	0.5769	0.6034	4,903,045
48001	0	26,367,160	24,126,417	2,240,743	1,675,947	1,580,834	2,869,792	1,913,178	1,818,500	74,215	11,751	0.6366	0.6507	5,605,923
50001	0	16,404,219	15,513,993	890,226	1,019,489	845,135	1,164,394	1,211,747	1,184,392	40,608	7,557	0.8156	0.8288	2,864,639
52001	0	28,366,948	27,139,365	1,227,583	1,871,523	1,544,973	2,164,215	2,176,418	2,136,378	56,593	13,219	0.7951	0.8023	5,339,206
54001	0	38,131,182	36,703,938	1,427,245	2,691,152	3,062,456	5,534,180	3,071,032	3,000,652	46,301	17,878	0.5547	0.5542	10,865,287
56001	0	10,277,460	10,030,671	246,789	672,825	714,598	1,382,511	842,186	835,624	13,997	4,886	0.6199	0.6202	2,703,421
58001	0	9,376,964	8,967,996	408,968	569,907	515,792	638,850	797,911	782,537	20,313	4,368	0.9433	0.9511	1,649,334
60001	0	2,740,239	2,712,255	27,984	166,596	165,362	255,392	243,230	242,526	1,799	1,321	0.8443	0.8366	581,352
62001	0	3,360,057	3,270,874	89,183	231,263	236,660	400,032	311,554	308,365	5,219	1,593	0.7318	0.7322	844,918
64001	0	15,677,377	15,381,421	295,956	1,001,495	973,967	1,492,613	1,519,425	1,520,614	30,448	7,492	0.8932	0.8963	3,402,605

and Scaled Equity Ratio by weight and axle class for the alternative rate analysis. The *Alt Equity* tab refers to the *Master VMT, Alt Revenues,* and *Allocated Costs* tabs.

Alt Revenues

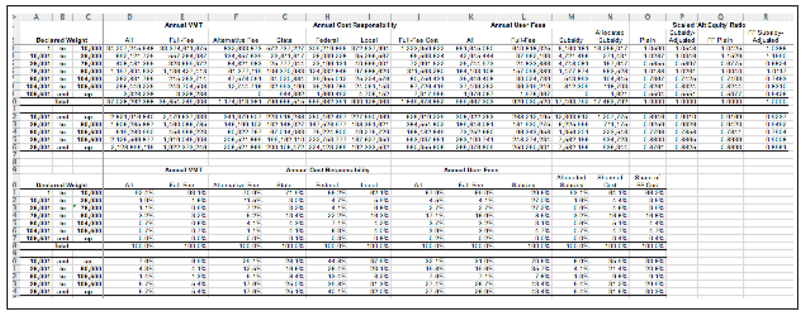
The *Alt Revenues* tab contains model output of the attributed revenues by major revenue instrument for each weight and axle class. The Alt Revenues are summed to produce Annual User Fees in the *Alt Equity* and *Alt Summary* tabs.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Weight Class	Axles	Gas Tax	Diesel Tax	VMT Tax	WMT	Flat Fee	RUAF	Registration	Other MC	Subsidy	Full Fee VMT
2	1	0	938,499,767	66,121,477	0	0	0	0	298,668,856	0	10,320,362	33,374,611,675
3	10,001	0	5,366,401	2,953,513	0	0	0	0	4,686,272	0	541,148	108,602,600
4	12,001	0	2,848,419	1,807,132	0	0	0	0	2,645,367	0	1,168,309	53,990,041
5	14,001	0	6,519,773	4,069,050	0	0	0	0	6,519,896	0	689,807	123,839,230
6	16,001	0	3,663,743	2,267,716	0	0	0	0	3,887,894	0	339,911	67,702,484
7	18,001	0	3,605,321	2,428,467	0	0	0	0	4,076,234	0	633,882	62,824,560
8	20,001	0	403,629	660,196	0	0	0	0	636,106	0	648,038	8,115,019
9	22,001	0	2,177,007	1,223,824	0	0	0	0	2,367,524	0	1,100,093	29,925,444
10	24,001	0	4,300,538	8,121,470	0	0	0	0	8,655,397	0	4,321,724	102,264,707
11	26,001	0	710,731	111,230	0	180,419	0	0	158,921	11,540	602,280	8,595,063
12	28,001	0	717,164	117,867	0	405,023	2,859	0	209,181	24,441	704,335	11,347,032
13	30,001	0	2,106,524	215,086	0	1,112,682	0	0	370,752	64,264	1,278,992	36,430,197
14	32,001	0	103,694	101,799	0	2,425,153	0	0	517,880	134,016	463,874	27,567,960
15	34,001	0	122,467	40,947	0	453,046	0	0	128,654	24,099	673,835	4,957,281
16	36,001	0	17,208	18,116	0	217,364	0	0	56,331	10,991	284,404	2,260,910
17	38,001	0	33,859	43,565	0	462,413	0	0	188,744	22,536	4,184,337	4,635,717
18	40,001	0	18,094	17,843	0	437,298	0	0	105,298	20,567	32,075	4,230,827
19	42,001	0	35,481	34,176	0	275,591	0	0	98,085	12,502	197,507	2,571,774
20	44,001	0	59,626	163,708	0	2,949,504	1,430	0	795,190	129,443	196,184	26,627,285
21	46,001	0	41,966	167,501	0	2,252,510	10,820	0	557,907	95,734	196,842	19,693,213
22	48,001	0	37,012	136,571	0	2,851,260	55,933	0	628,294	117,286	148,430	24,126,417
23	50,001	0	3,743	70,654	0	1,901,240	5,081	0	367,359	75,418	81,215	15,513,993
24	52,001	0	7,487	100,191	0	3,449,685	9,416	0	654,125	131,932	113,187	27,139,365
25	54,001	0	4,254	93,402	0	4,839,781	60,733	0	965,465	178,428	92,602	36,703,938
26	56,001	0	473	15,463	0	1,377,913	3,145	0	238,616	48,762	27,994	10,030,671
27	58,001	0	1,772	30,251	0	1,288,163	10,870	0	221,169	43,596	40,626	8,967,996

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 Fee 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 rate changes on the 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 Tax

This 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 current (2011 HCAS) rates.

Follow these steps for an alternative rate analysis of an increase in the gas and diesel tax rates:

1. In the *Alt Rates* tab, copy the current rates using the "Copy Current Rates" button.
2. In the Gas Tax column (column "C" beginning in row 21) enter 0.36 for each weight class. This step specifies the alternative gas tax rate of $0.36 per gallon.
3. In the Diesel Tax column (column "D" beginning in row 21) enter 0.36 for each weight class. This step specifies the alternative diesel tax rate of $0.36 per gallon.
4. Go to the *Control* tab (left-most tab in the HCAS Model workbook). Click the "Recalculate" button to run the model using the new gas and diesel tax rates specified in the *Alt Rates* tab.

5. View the alternative rate analysis results in the *Alt Equity, Alt Revenues,* and *Alt Summary* tabs.

The revenue in the *Alt Revenues* tab will now reflect the increase in the gas and diesel tax rates.

Comparing the *Equity* tab output to the *Alt Equity* tab output, one can see 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 4 compares the gas tax revenue, diesel tax revenue, and other revenue for the 2011 HCAS model and the Gas Tax/Diesel Tax Alternative Analysis. 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 5). 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.

Table 4: Comparison of Annual Revenues from an Alternative Rate Analysis of an Increase in the Gas and Diesel Tax Rates (thousands of dollars)

Revenue Source	HCAS 2011 Final	Alternative Rate Analysis	Difference in Revenues	Percent Change in Revenues
Gas Tax Revenues	493,090	591,708	98,618	20%
Diesel Tax Revenues	42,798	51,357	8,560	20%
Other Revenues	590,345	590,345	0	0%
Total Revenue	1,126,232	1,233,410	107,178	9.5%

Table 5: Comparison of Revenue Shares and Equity Ratios for Gas and Diesel Tax Case

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratio	
	HCAS 2011	Alternative	HCAS 2011	Alternative
1 to 10,000	65.73%	68.42%	0.9954	1.0363
10,001 and up	34.27%	31.58%	1.0089	0.9295

Case Study B: Change in Registration Fee

In the second case study, a change in registration fees, we consider increasing the normal registration fee for basic vehicles from $43 to $54 per year.

Perform an alternative rate analysis of a change in the Normal Registration Fee by following these steps:

1. In the *Alt Rates* tab, copy the current rates using the "Copy Current Rates" button.
2. In the Normal Reg column (column G beginning in row 21), 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).
3. Go to the *Control* tab and click the "Recalculate" button to recalculate the model output using the new registration fee specified in the *Alt Rates* tab.
4. View the alternative rate analysis results in the *Alt Equity, Alt Revenues,* and *Alt Summary* tabs.

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 34.27 percent to 33.15 percent, as shown in Table 6.

Table 6: Comparison of Revenue Shares and Equity Ratios for Basic Vehicle Registration Fee Case

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratio	
	HCAS 2011	Alternative	HCAS 2011	Alternative
1 to 10,000	65.73%	66.85%	0.9954	1.0123
10,001 and up	34.27%	33.15%	1.0089	0.9761

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 tax.

Perform an alternative rate analysis of a new VMT tax and repeal of the gas and diesel tax by following these steps:

1. In the *Alt Rates* tab, copy the current rates using the "Copy Current Rates" button.
2. In the Gas Tax and Diesel Tax columns (columns C and D beginning in row 21), enter 0 for all weight classes. This step sets the gas and diesel tax rates to zero.
3. In the VMT Tax column (column E, beginning in row 21), enter 0.0293 for all weight classes. This step sets the VMT tax rate to $0.0293 per mile (2.93 cents per mile).
4. Go to the *Control* tab (left-most tab in the HCAS Model workbook). Click the "Recalculate" button to run the model using the new VMT tax specified in the *Alt Rates* tab.
5. View the alternative rate analysis results in the *Alt Equity, Alt Revenues,* and *Alt Summary* tabs.

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 7.

Table 7: Comparison of Revenue Shares and Equity Ratios for VMT Tax Case Study

Weight Class	Share of Annual User Fees		FF Subsidy-Adjusted Equity Ratio	
	HCAS 2011	Alternative	HCAS 2011	Alternative
1 to 10,000	65.73%	75.88%	0.9954	1.1494
10,001 and up	34.27%	21.12%	1.0089	0.7098

2011 HCAS Model Documentation

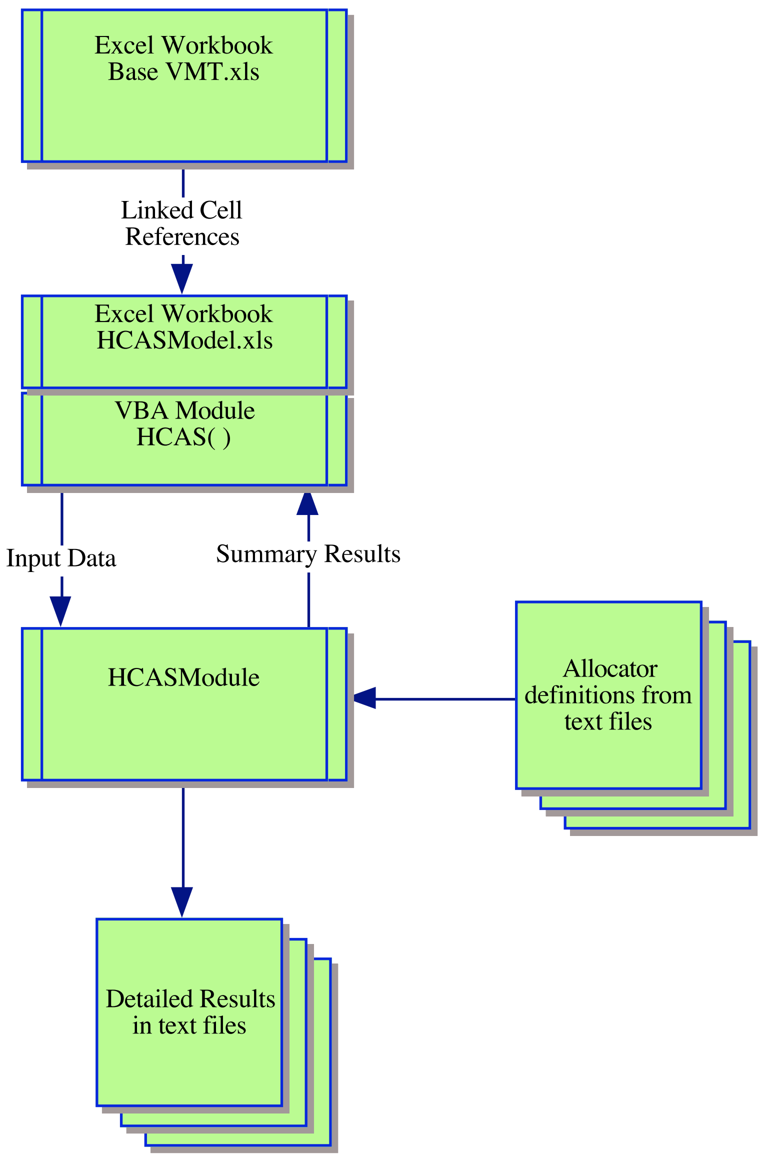
The full source code for the 2011 Oregon Highway Cost Allocation Model is included with the model distribution. The model is contained within a class that can be run by Excel as an Active-X module and each of the class methods within it can be called from within Excel.

This document begins with a description of the Visual Basic for Applications (VBA) routine that runs when the "Recalculate" button on the *Control* tab of the HCASModel.xls workbook is pressed. The routine makes a series of calls to the Active-X module, sending data from Excel and then retrieving calculated results back and pasting them into worksheets.

This document then provides a detailed description of each of the class methods that are called by the VBA routine, explaining the calculations and describing the internal data structures they use.

Figure 1 shows a graphical representation of the overall model, including the Excel workbooks, the VBA within the model workbook, the external code module, and the external data files.

Figure 1: Oregon Highway Cost Allocation Model



Description of Model Calculation Operations

The following describes what happens when the “Recalculate” button is pressed. The “Recalculate” button is connected to the HCAS() subroutine in the workbook’s VBA module. That subroutine is described line-by-line here. These lines are always executed in the order shown and every line is executed with every recalculation.

Initialization

```
Sub HCAS()

    ChDrive (ActiveWorkbook.Path)

    ChDir (ActiveWorkbook.Path)

    Set HCASModel = CreateObject(“HCASModule”)
```

The first two lines of the HCAS() routine allow the model to work if the workbook was opened by double-clicking the workbook file. They set Excel’s path to the drive and directory where the workbook resides, assuming that HCASModule.py and the text files it needs are located in the same directory.

The third line loads the HCASModule into memory. When the HCASModule loads, it runs its initialization methods. Those methods read in data from seven text files. These data are:

SeedData. Used to populate a preliminary VMT Master table for iterative proportional fitting (described below).

AxleShares. 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).

SimpleFactors. A vector 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.

PaveFactors. 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 new National Pavement Cost Model for Highway Cost Allocation developed by Roger Mingo).

PCEFactors. Passenger car equivalents (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 the results of a special study conducted as a part of the 1997 Federal Highway Cost Allocation Study.

DeclaredOperating. Shares of vehicles in each declared weight class operating at each operating weight class. These data were developed from the Special Weighings and Weigh-in-Motion data.

DeclaredRegistered. 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.

BasicSharePeak. The basic-vehicle share of peak-hour VMT for each functional class. These data were developed from automatic traffic recorder data.

Send Base-Year VMT Data and Retrieve Model-Year VMT Data

```
Call HCASModel.setGrowthRates([GrowthRates].Value)

Call HCASModel.setVMTByFC([VMTByFC].Value)

Call HCASModel.setBaseVMT([BaseVMT].Value)

Call HCASModel.setEvasion([Evasion].Value)
```

The next four lines send input data from the workbook to the HCASModule so that it can calculate model-year VMT.

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 *Revenues* tab, tell the model what evasion and avoidance rates to assume. Evasion and avoidance are combined.

```
vmtMaster = HCASModel.makeVMTMaster()

Sheets("VMT Master").Activate

[A3:D5117].Value = vmtMaster

modelVMT = HCASModel.makeVMTByVehicles()

Sheets("Model VMT").Activate

[A3:AB99].Value = modelVMT
```

The call to makeVMTMaster() tells the model to do its VMT calculations and send back a portion of the Master VMT table, which is pasted into the *VMT Master* tab. The call to makeVMTByVehicles() tells the model to calculate model-year VMT by weight and tax class and send those back, where they are pasted into the *Model VMT* tab.

Send Costs to Allocate and Retrieve Allocated Costs

```
Call HCASModel.setPath([Path].Value)
```

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.

```
Call HCASModel.setProjectCosts([ProjectCosts].Value)

Call HCASModel.setNonProjectCosts([NonProjectCosts].Value)

Call HCASModel.setLocalCosts([LocalCosts].Value)
```

The next three lines send costs to allocate to the model 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 not a bridge project.

```
Call HCASModel.setStuddedTire([StuddedTire].Value)
```

The next line sends studded-tire adjustments from the *Studded Tires* 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.

```
Call HCASModel.setBridgeFactors([BridgeFactors].Value)
```

The next line sends bridge factors from the *Bridge Splits* 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.

```
Call HCASModel.setBondFactor([BondFactor].Value)

Call HCASModel.setBiennium([Biennium].Value)
```

The next two lines send information necessary for the proper treatment of the expenditure of bond revenues. Both come from the *Control* tab.

```
Call HCASModel.setSummaryWorkTypes([SWT].Value)

Call HCASModel.setSummaryWeightClasses([SWC].Value)
```

The next two lines send information from the *Codes* tab that 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 the workbook, because it is faster, more reliable, and keeps the workbook size reasonable.

```
allocatedCosts = HCASModel.allocateCosts()

Sheets("Allocated Costs").Activate

[A3:I343].Value = allocatedCosts
```

The call to allocateCosts() tells the model to allocate costs and return the allocated costs by weight class and funding source, which are then pasted into the *Allocated Costs* tab.

Send Revenues and Rates and Retrieve Attributed Revenues

```
Call HCASModel.setRevenueTotals([RevenueTotals].Value)

Call HCASModel.setRates([Rates].Value)

Call HCASModel.setRUAFRates([RUAFRates].Value)

Call HCASModel.setFFRates([FFRates].Value)
```

The next four lines send information from the *Revenues* tab to the model. Revenue totals are the control totals by instrument from the budget. 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.

```
Call HCASModel.setMPG([MPG].Value)
```

The next line sends estimated miles per gallon by operating weight class from the *MPG* tab.

```
attributedRevenues = HCASModel.attributeRevenues()

Sheets("Attributed Revenues").Activate

[A1:K342].Value = attributedRevenues
```

The call to attributeRevenues() tells the model to attribute revenues and return the attributed revenues by weight class and revenue instrument, which are then pasted into the *Attributed Revenues* tab.

```
adjustedMPG = HCASModel.getAdjustedMPG()

Sheets("MPG").Activate

[D3:E100].Value = adjustedMPG
```

The call to getAdjustedMPG() tells the model to return the adjusted miles per gallon (already calculated as part of the revenue attribution calculations), which are then pasted into the "MPG" tab 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

```
AllocatedCostsbySWT = HCASModel.getAllocatedCostsByWorkType()

Sheets("Allocated Costs by SWT").Activate

[B3:J171].Value = AllocatedCostsbySWT
```

The call to getAllocatedCostsByWorkType() tells the model to send allocated costs by summary work type, funding source, and summary weight class, which are then pasted into the *Allocated Costs by SWT* tab.

```
CostsToAllocatebySWT = HCASModel.getCoststoAllocate()

Sheets("Costs to Allocate by SWT").Activate

[B3:I27].Value = CostsToAllocatebySWT
```

The call to getCostsToAllocate() tells the model to return costs to allocate by summary work type and funding source, which are then pasted into the *Costs to Allocate by SWT* tab.

Retrieve Scaled Allocation Vectors

```
AllocationVectors = HCASModel.getAllocationVectors()

Sheets("Allocation Vectors").Activate
```

```
[A2:T5117].Value = AllocationVectors
```

The call to getAllocationVectors tells the model to return the scaled allocation vectors. These are the allocation vectors after they have been weighted by model-year VMT and then scaled so they add up to one. They are pasted into the *Allocation Vectors* tab.

Send Alternative Rates and Retrieve Attributed Alternative Revenues

```
Call HCASModel.setAltRates([AltRates].Value)

Call HCASModel.setAltRUAFRates([AltRUAFRates].Value)

Call HCASModel.setAltFFRates([AltFFRates].Value)
```

The next three lines send alternative rates from the *Alt Rates* tab to the model. 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.

```
attributedRevenues = HCASModel.attributeAltRevenues()

Sheets("Alt Revenues").Activate

[A1:L342].Value = attributedRevenues
```

The call to attributeAltRevenues() tells the model to attribute revenues using the alternative rate schedules and return results by weight class and revenue instrument. Those are pasted into the *Alt Revenues* tab.

```
Sheets("Summary").Activate
```

The last line of the HCAS() routine leaves the workbook with the *Summary* tab open so the user can see the summary results of the model run.

Table 1 describes the input ranges in various tabs of the HCASModel.xls 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 moves the data to the external model code, and the name of the data structure in the external model code that accepts the data.

Table 2 describes the tab-delimited text files that contain input data for the external model code, listing the file name, what data each contains, the units the data are in, and the data structure in the external model code that accepts the data.

Table 3 describes the outputs from the external model code that are sent back to the HCASModel.xls workbook, listing the data structure in the external model code from which the data are extracted, the method called to calculate and retrieve the data, the tab into which the data are pasted, the upper-left corner of the cell range into which the data are pasted, and the contents of the data.

Table 4 describes the tab-delimited text files that are written when the external model code runs, listing the data structure in the external model code 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 Input Ranges

Excel Range	Tab	Contains	Units	Method to Send to Model	Model Data Structure
GrowthRates	VMT Growth	VMT growth rates	annual growth rate (e.g., 0.05 means 5% per year)	setGrowthRates()	self.growthRates
VMTByFC	VMT by FC	VMT by functional class and ownership	Base-year vehicle-miles traveled	setVMTByFC()	self.VMTbyFC
BaseVMT	Base VMT	Base-year VMT by weight class and tax class	Base-year vehicle-miles traveled	setBaseVMT()	self.baseVMT
Evasion	Revenue	assumptions for gas-tax avoidance, use-fuel tax evasion and 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	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	setEvasion()	self.gasEvasion, self.dieselEvasion, self.wmtEvasion, self.basicDiesel, self.ruafRegRate, self.ruafReg78, self.ruafReg96, self.ruafReg104, self.emptyLogPercent, self.emptyLogWeight
Path	Policy	Allocator(s) to use for each work type	names of allocators and shares	setPath()	self.path
ProjectCosts	Project Costs	Costs to allocate for construction projects	biennial dollars	setProjectCosts()	self.projectCosts
NonProjectCosts	Non-Project Costs	Other costs to allocate	biennial dollars	setNonProjectCosts()	self.nonProjectCosts
LocalCosts	Local Costs	Local-government costs to allocate	biennial dollars	setLocalCosts()	self.localCosts
StuddedTire	Studded Tires	Studded-tire adjustments	biennial dollars	setStuddedTire()	self.studdedTire
BridgeFactors	Bridge Splits	Incremental factors for bridge work types	shares	setBridgeFactors()	self.bridgeFactors
BondFactor	Control	Proportion of bonded expenditures to allocate in a biennium	share	setBondFactor()	self.bondFactor
Biennium	Control	First year of model biennium	four-digit year	setBiennium()	self.biennium
SWT	Codes	Definitions of summary work types	work type codes	setSummaryWorkTypes()	self.summaryWorkTypes
SWC	Codes	Definitions of summary weight classes	pounds	setSummaryWeightClasses()	self.summaryWeightClasses
RevenueTotals	Revenue	Control totals for revenues by instrument	biennial dollars	setRevenueTotals()	self.revenueTotals
Rates	Revenue	Current-law rates except RUAF and flat fee	dollars per whatever	setRates()	self.rates
RUAFRates	Revenue	Current-law RUAF rates	dollars per mile	setRUAFRates()	self.RUAFRates
FFRates	Revenue	Current-law flat fee rates	dollars per month, miles per month, and shares	setFFRates()	self.flatfee
MPG	MPG	Assumed miles per gallon	miles per gallon	setMPG()	self.MPG
AltRates	Alt Revenues	Alternative rates except RUAF and flat fee	dollars per whatever	setAltRates()	self.altRates
AltRUAFRates	Alt Revenues	Alternative RUAF rates	dollars per mile	setAltRUAFRates()	self.altRUAFRates
AltFFRates	Alt Revenues	Alternative flat fee rates	dollars per month, miles per month, and shares	setAltFFRates()	self.altFlatfee

Table 2 Input Text Files

Text File	Contains	Units	Model Data Structure
SeedData.txt	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.	unitless numbers	self.seedData
AxleShares.txt	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	shares (e.g., 0.5 means 50%)	self.shares
SimpleFactors.txt	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.	shares	self.simpleFactors
PaveFactors.txt	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.	shares	self.paveFactors
PCEFactors.txt	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.	shares	self.pceFactors
DeclaredRegistered.txt	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.	shares	self.declaredRegistered
DeclaredOperating.txt	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.	shares	self.declaredOperating
BasicSharePeak.txt	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.	shares	self.peakShares
BondsYYYY-YYYY.txt	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".	biennial dollars	self.priorBondAmount

Table 3 Outputs

Model Data Structure	Method to Retrieve	Tab	Upper Left	Contains
self.VMTMaster	makeVMTMaster()	VMT Master	A3	Model-year VMT by declared weight class, declared axles, functional class, and ownership
self.vmtByVehicles	makeVMTByVehicles()	Model VMT	A3	Model year VMT by weight class and tax class
self.fullAllocatedCosts	allocateCosts()	Allocated Costs	A3	Allocated costs by declared weight class, declared number of axles, and funding source
attributedRevenues	attributeRevenues()	Attributed Revenues	A1	Attributed revenues by declared weight class, declared number of axles, and revenue instrument
self.adjustedMPG	getAdjustedMPG()	MPG	D3	Calibrated estimates of miles per gallon by weight class
self.fullAllocatedCosts	getAllocatedCostsByWorkType()	Allocated Costs by SWT	B3	Allocated costs by funding source, summary work type, and summary weight class
self.projectCosts, self.nonProjectCosts, self.bondCosts, self.priorBondAmount	getCoststoAllocate()	Costs to Allocate by SWT	B3	Costs to allocate by funding source and summary work type
self.allocators	getAllocationVectors()	Allocation Vectors	A2	Allocation factors used in cost allocation by declared weight class, declared number of axles, and allocator
attributedRevenues	attributeAltRevenues()	Alt Revenues	A1	Attributed alternative revenues by declared weight class, declared number of axles, and revenue instrument

Table 4 Output Text Files

Model Data Structure	Method to Create	Contains	Units	File Name
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_bond.txt
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_federal.txt
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_local-federal.txt
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_local-other.txt
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_local-state.txt
self.fullAllocatedCosts	allocateCosts()	Not used. This may be ignored.	biennial dollars	allocatedCosts_other.txt
self.fullAllocatedCosts	allocateCosts()	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.	biennial dollars	allocatedCosts_state.txt
allocatedBonds	allocateCosts()	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".	biennial dollars	BondsYYYY-YYYY.txt
self.pavement	makeVMTMaster()	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.	unitless factors	declared_pave_factors.txt
ffRevenue, asifWMTRevenue	allocateCosts()	Reports fees paid by flat-fee vehicles and the fees they would pay if they paid weight-mile tax. The ‘as-if‘ revenue is for comparison 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.	biennial dollars	flat_fee_report.txt
N/A	makeVMTMaster()	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.	N/A	missing_pavement_factors.log
self.VMTMaster	makeVMTMaster()	Contains annual VMT. Columns are functional class, ownership, declared weight class, declared number of axles, and vehicle-miles traveled. The first four are keys.	annual vehicle-miles traveled	VMTMaster.txt
ffRevenue, regRevenue, ruafRevenue, wmtRevenue, gasTaxRevenue, dieselTaxRevenue, asifWMTRevenue	allocateCosts()	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.	biennial dollars	SubsidiesbyVehClass.txt

Detailed Description of Class Methods in the Model

This part of the documentation serves two purposes: it describes in detail how the model does what it does and it 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 by the VBA subroutine. Line numbers from the version of the code included with the 2011 model distribution are included to facilitate following the source code.

Class Methods for Getting Data Into the Model

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 transferred from the Excel workbook that runs the model.

Other class methods, described in later sections, make use of the data and return results to Excel. Some also write 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.

The readData() method (line 16) is run during initialization and imports the following data sets from tab-delimited text files, which are expected to be in the same directory as the model:

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.

AxleShares.txt is read into self.shares and 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 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.

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.

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 Special Weighings 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 registration data. There are three columns: declaredWeight, registeredWeight, 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.

The following class methods capture data from Excel (user inputs) for the VMT calculations. Excel calls these methods to give data to the model before it calls the makeVMTMaster method.

setGrowthRates() (line 70) 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.

setVMTByFC() (line 77) 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 FWHA Highway Statistics reports.

setBaseVMT() (line 84) 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 94) captures evasion and avoidance rates, along with some other assumptions used in revenue attribution, and puts them 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)

These assumptions are specified by the analyst.

The following class methods capture data from Excel (user inputs) for the cost allocation calculations. Excel calls these methods to give data to the model before it calls the allocateCosts() method.

setPath() (line 114) 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.

setNonProjectCosts() (line 124) 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.

setProjectCosts() (line 134) 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.

setLocalCosts() (line 144) 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.

setStuddedTire() (line 154) 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 163) captures cost shares used to distribute bridge expenditures for incremental cost allocation and puts them into self.bridgeFactors. self.BridgeFactors is 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.

setBondFactor() (line 172) captures the bond factor, which is the proportion of bond-funded expenditures that will be repaid in a single biennium, and puts it into self.bondFactor. This assumption is specified by the analyst. It represents the biennial repayment amount as a proportion of the principal amount.

setBiennium() (line 177) captures the starting year of the model biennium and puts it into self.biennium. Specified by the analyst.

The following class methods capture data from Excel (user inputs) for the revenue attribution calculations. Excel calls these methods to give data to the model before calling the attributeRevenues() method.

setRevenueTotals() (line 188) 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.

setRates() (line 198) captures 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. self.rates 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. These are specified by the analyst based on current law and must match the assumptions used to develop the revenue control totals.

setRUAFRates() (line 222) captures current-law road-use assessment fee rates and puts them into self.RUAFRates. The key is a tuple consisting of weight class and number of axles and values are dollars per mile. These are specified by the analyst based on current law.

setFFRates() (line 236) captures current-law monthly flat-fee rates, average monthly miles, and axle distribution and puts them into self.flatfee. 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. 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.

setMPG() (line 260) 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.

The following class methods capture data from Excel (user inputs) for the alternative revenue attribution calculations. Excel calls these methods to give data to the model before calling the attributeAltRevenues() method.

setAltRates() (line 210) captures alternative rates for 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.altRates. 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. These are specified by the analyst to test proposed changes to rates.

setAltRUAFRates() (line 229) captures alternative road-use assessment fee rates and puts them into self.altRUAFRates. The key is a tuple consisting of weight class and number of axles and values are dollars per mile. These are specified by the analyst to test proposed changes to rates.

setAltFFRates() (line 248) captures current-law monthly flat-fee rates, average monthly miles, and axle distribution and puts them into self.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. These are specified by the analyst to test proposed changes to rates.

The following class methods capture data from Excel (user inputs) for use in tabulating summary tables of allocated costs and costs to allocate. Excel calls these methods to give data to the model before calling the getAllocatedCostsByWorkType() and getCostsToAllocate() methods.

setSummaryWorkTypes() (line 272) 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.

setSummaryWeightClasses() (line 279) 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

The **makeVMTMaster()** method (line 292) 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 307) sums VMTData by functional class and ownership across weight classes and numbers of axles.

findVCSums() (line 315) sums VMTData by weight class and number of axles across functional class and ownership.

scaleToFC() (line 323) multiplies each value in VMTData by the ratio of its FCTotal control total to its current FCSum.

scaleToVC() (line 330) multiplies each value in the VMTData by the ratio of its VCTotal control total to its current VCSum.

findSSE() (line 337) 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, go back 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 Excel.

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.

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 503) 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 Excel. self.vmtByVehicles is a nested dictionary. The outer key is the tax class and the inner key is the weight class.

Cost Allocation

The allocateCosts() method (line 532) performs the following processes:

- Combine local costs data from self.localCosts with project costs data from self.projectCosts into self.projectCosts (line 537).
- Do bridge splits on project costs (line 541). 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 556). 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 563). 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 586). 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 640). 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 648).
- Make Other Bridge and Other Construction allocators (line 661). 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 705).
- Apply allocators to non-project costs (line 719). 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 741). Applies the allocators to bondstoAllocate and stores the result in allocatedBonds.
- Store allocated bonded costs (line 757). 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 773). Captures allocated, current payments due on bonds issued for projects in previous biennia (priorBonds).
- Add current and prior allocated bonded costs to allocatedCosts (line 795).
- Write out detailed allocation results to tab-delimited text files, one for each funding source (line 807). These are named allocatedCosts_federal.txt, allocatedCosts_state.txt, etc.
- Copy allocators to self.allocators and allocatedCosts to self.fullAllocatedCosts (line 823).
- Prepare a summary table of allocated costs and send it back to Excel (line 826). 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 846) gets the allocation vectors from self.allocators and returns them to Excel. Columns are allocators and rows are combinations of facility class, declared weight class, and declared number of axles.

The getAllocatedCostsByWorkType() method (line 877) 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 Excel. 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 913) 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 and returns the aggregated costs to allocate to Excel. 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

The attributeRevenue() method (line 950) performs the following processes:

- Attribute road-use assessment fee (RUAF) revenue (line 950). RUAF 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 RUAF rate from self.RUAFRates. RUAF VMT are the total VMT in that combination of weight class and number of axles from self.VMTMaster times the ratio of RUAF VMT in that weight class to all VMT in that weight class from self.vmtByVehicles. This assumes that axle shares for RUAF 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 RUAF 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 966). WMT revenues are attributed to weight classes by multiplying their model-year VMT in each combination of weight class and number of axles form 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 RUAF, 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 993). 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, flat_fee_report.txt, containing flat-fee VMT, revenues, and as-if WMT revenues by commodity and weight class is written out to disk.
- Attribute registration and title revenues (line 1023). 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 RUAF 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 *Revenues* tab of the 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 vehicles 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 1178). 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 1200). 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 sent back to Excel 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 1282). 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 1316). 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 and send it back to Excel (line 1338).

getAdjustedMPG() (line 1360) returns the calibrated miles-per-gallon assumptions from self.adjustedMPG to Excel.

Alternative Revenue Attribution

attributeAltRevenues() (line 1376) repeats the revenue attribution process using alternative rates specified by the analyst in the *Alt Rates* tab of the 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.

Running the HCASModule as a Stand-Alone Program

When the HCASModule is run as a stand-alone program (by double-clicking HCASModule.py, from a command prompt, or through the "Run..." dialog), no class object is created and none of the methods described are run. Instead, the code on lines 1712 to 1716 runs and registers the module as an Active-X object in the Windows registry. This allows Excel to find and use the module and its methods. The module must be registered before the first use of the model and again any time the model and module code are moved to another directory in the user's hard drive (the entire directory must be kept together). The user who registers the module must have permission to write to the Windows registry. If registration doesn't work (a message will appear saying you don't have permission), ask your IT staff to do it for you. Once the module is registered, any user can use it.

Documentation of Final 2011 HCAS Model Run

This appendix documents the assumptions and data used in the final run of the HCAS model for the 2011 Highway Cost Allocation Study. Data used in the final model run were collected between roughly June 2009 and January 2011. The final model run was completed and verified in January 2011.

Table 1 lists the assumptions used in the Base VMT workbook. These assumptions are yellow-shaded cells in their respective workbook tabs. Table 2 lists the assumption used in the *Studded Tire* tab in the Split PE and ROW workbook.

Table 3 lists the assumptions in the HCAS Model workbook. The HCAS Model workbook tab is listed in the first column followed by the assumption name or brief description. All of the assumptions listed in Table 3 correspond to yellow-shaded cells in their respective workbook tab.

Tables 4 through 6 display the assumptions for the motor home weight

Table 1: Base VMT Workbook Assumptions

Tab	Assumption	Value
DMV-Other	Commercial Trucks and Buses Avg Annual VMT per vehicle (10,001 weight class)	11,000
DMV-Other	Commercial Trucks and Buses Avg Annual VMT per vehicle (12,001 weight class)	10,000
DMV-Other	Commercial Trucks and Buses Avg Annual VMT per vehicle (14,001 weight class)	9,000
DMV-Other	Commercial Trucks and Buses Avg Annual VMT per vehicle (16,001-24,001 weight class)	8,000
DMV-Other	Tow Truck Annual VMT per vehicle	15,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (less than 20,001 weight class)	3,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (20,001 to 40,000 weight class)	3,500
DMV-Other	Farm Vehicle Annual VMT per vehicle (40,001 to 50,000 weight class)	4,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (50,001 to 70,000 weight class)	4,500
DMV-Other	Farm Vehicle Annual VMT per vehicle (70,001 to 80,000 weight class)	5,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (80,001 to 90,000 weight class)	6,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (90,001 to 100,000 weight class)	7,000
DMV-Other	Farm Vehicle Annual VMT per vehicle (100,001 to 104,000 weight class)	7,500
DMV-Other	Farm Vehicle Annual VMT per vehicle (104,001and up weight class)	8,000
DMV-Other	Charitable and Non-Profit Avg Annual VMT per vehicle	10,000
DMV-Other	State and Local Avg Annual VMT per vehicle Less than 10,001 Weight Class	13,000
DMV-Other	State and Local Annual VMT-10,001-26,001 Weight Classes	12,000
DMV-Other	State and Local Annual VMT over 26,001 Weight Classes	11,000
Motorhomes	Motorhome Annual VMT	7,000
SchoolBus	Private School Bus adjustment factor	1.50%
Transit	Transit adjustment factor	1.02
Motorhomes	Motorhome length/weight class assumptions (from Winnebago vehicle spec information)	Various- See Table 4

Table 2: Split PE and ROW Workbook Assumptions

Tab	Assumption	Value
Studded Tires	% State (% of Construction State funded)	10.27%

Table 3: HCAS Model User-Specified Assumptions

Tab	Assumption	Justification/Source	Value
Bridge Splits	Split of bridge expenditures across bridge reclassification work types	2002 OBEC Bridge Allocation Study	Various-See Table 5
Control	Base Year	page 2-1	2009
Control	Biennium	page 2-1	2011
Control	BondFactor	page 3-10	0.1605
Control	Forecast Year (also, Model Year)	page 2-1	2012
Gas and Diesel	Percent of basic gallons that are diesel	NA	6.75%
Gas and Diesel	Percent of RV gallons that are diesel	NA	40%
Gas and Diesel	Percent of taxed gallons that are basic	NA	96%
MPG	MPG (initial) by weight class	Regression on 2002 VIUS data	Various-See Table 6
Policy	Preliminary and Construction Engineering (and etc.) Share 1	page 3-4 through 3-8	55.95%
Policy	Right of Way (and Utilities) Share 1	page 3-4 through 3-8	73.75%
Policy	New Pavements-Rigid Allocator/Share 1	page 3-4 through 3-8	6.92%
Policy	New Pavements-Flexible Allocator/Share 1	page 3-4 through 3-8	4.46%
Policy	Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	page 3-4 through 3-8	26.92%
Policy	Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	page 3-4 through 3-9	24.46%
Policy	Pavement and Shoulder Rehab-Flexible Allocator/Share 1	page 3-4 through 3-10	24.46%
Policy	Pavement and Shoulder Rehab-Flexible Allocator/Share 1	page 3-4 through 3-11	24.46%
Policy	Surface and Shoulder Maintenance-Rigid Allocator/Share 1	page 3-4 through 3-12	26.92%
Policy	Surface and Shoulder Maintenance-Flexible Allocator/Share 1	page 3-4 through 3-13	24.46%
Policy	Local Gov :Preliminary and Construction Engineering (and etc.) Share 1	page 3-4 through 3-14	55.92%
Policy	Local Gov :Right of Way (and Utilities) Share 1	page 3-4 through 3-15	55.92%
Policy	Local Gov :New Pavements-Rigid Allocator/Share 1	page 3-4 through 3-16	8.08%
Policy	Local Gov :New Pavements-Flexible Allocator/Share 1	page 3-4 through 3-17	7.58%
Policy	Local Gov :Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	page 3-4 through 3-18	28.08%
Policy	Local Gov :Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	page 3-4 through 3-19	27.58%
Policy	Local Gov :Pavement and Shoulder Rehab-Flexible Allocator/Share 1	page 3-4 through 3-20	27.58%
Policy	Local Gov :Pavement and Shoulder Rehab-Flexible Allocator/Share 1	page 3-4 through 3-21	27.58%
Policy	Local Gov :Surface and Shoulder Maintenance-Rigid Allocator/Share 1	page 3-4 through 3-22	28.10%
Policy	Local Gov :Surface and Shoulder Maintenance-Flexible Allocator/Share 1	page 3-4 through 3-23	27.60%
Policy	All other Allocators Shares for work types not Prelim. Engineering, ROW, or Pavement	page 3-4 through 3-24	100%
Revenues	Gas Tax Avoidance Rate	pages 3-10 and 3-11	3.53%
Revenues	Diesel Tax Evasion & Avoidance Rate	pages 3-10 and 3-11	4.53%
Revenues	WMT Evasion Rate	pages 3-10 and 3-11	5.00%
Revenues	RUAF Registration Adjustment	NA	0.045
Revenues	RUAF Reg. from 78001	NA	14.00%
Revenues	RUAF Reg. from 96001	NA	15.00%
Revenues	RUAF Reg. from 104001	NA	71.00%
Revenues	Log truck miles empty	page 7-4	50.00%
Revenues	Empty log truck declared weight (lbs)	page 7-4	42,001
Revenues	E-Plate Registration, annualized	One-time registration fee of $2 divided by 5 years.	0.40
Studded Tires	State/Local-State split	NA	0.11
Studded Tires	Preservation costs inflation rate	NA	0.03
VMT Growth	Growth rates for heavy vehicle weight classes	NA	various-see table

classes, bridge splits, and initial mpg because these assumptions are tables or ranges, not single values.

Table 4 displays the assumed weight classes by motor home length used to assign motor home VMT to weight classes in the *Motor homes* tab in the Base VMT 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

Table 4: Motor Home Vehicle 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

Table 5: Bridge Split Assumptions

Bridge Type	Work Type	Share
0	60	0.6098
0	61	0.2878
0	62	0.0333
0	63	0.0691
0	64	0
1	60	0.6098
1	61	0.2878
1	62	0.0333
1	63	0.0691
1	64	0
2	60	0.6176
2	61	0.2909
2	62	0.0136
2	63	0.0779
2	64	0
3	60	0.4324
3	61	0.2213
3	62	0.0565
3	63	0.2898
3	64	0
4	60	0.7962
4	61	0.0752
4	62	0.0875
4	63	0.0411
4	64	0

Table 6: MPG Assumptions (Initial MPG)

Declared	MPG	Declared	MPG
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
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
104,001	5.10		

Vehicle Inventory and Use Survey was discontinued after 2002.

Table 7 lists the files and sources of the data used in the 2011 Final HCAS model run. Following Table 7 is the SQL code used for pre-processing the DMV and WMT data. All other transformations of the raw data are described in Appendix D-HCAS User Guide.

Table 7: 2011 HCAS Data Files and Sources

Data	Source	Date	File Name
Bridge Project Information	Teresa Yih, Bridge Section ODOT	Nov-10	Proj Costs-Unkn Bridges and Costs to Breakout (Nov 17).xls
DMV Registration Data	Lani Pennington, ODOT	Jul-10	DMV_2009.txt, DMV_PermReg_2009.txt
Federal Fleet Report FY 2009	http://www.gsa.gov/graphics/ogp/FedealFleetReport2009rev.pdf	Jul-10	FederalFleetReport2009rev.pdf
FHWA Highway Statistics-Table MV7	http://www.fhwa.dot.gov/policyinformation/statistics/2009/mv7.cfm	Jan-11	FHWA Highway Statistics-Table MV7 (2009)
FHWA Highway Statistics-Table VM2	http://www.fhwa.dot.gov/policyinformation/statistics/2008/vm2.cfm	Nov-10	FHWA Highway Statistics-Table VM2 (2008)
Flat Fee Collections Reports	Lani Pennington, ODOT	Sep-10	FF_Final.xls, FF_for_Consultant.xls
OR HPMS Submittal Data	Jennifer Campbell, HPMS Coordinator, ODOT	Jun-10	2009OR_HPMS.csv
Local Costs: Local Roads and Streets Survey	Jon Oshel, AOC	Oct-10	FY2009 City & County.xls
Motor Carrier Registrations	Lani Pennington, ODOT	Jun-10	MTCD_reg_2009.csv
Non-Project Costs	Lani Pennington, ODOT	Nov-10	Costs to Allocate 2010_final.xls
Oregon Bridge Log 2008	http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/brlog.pdf	Oct-10	brlog08.pdf
Pavement Factors	Roger Mingo, Mingo and Assoc.	Jan-11	LRS_structure.doc, ODOT Pavement Structure Data.mdb, pavement type codes.xls, Surface Descriptions.csv, tpvmtbe.csv
Project Costs	Tessa Janzi, ODOT	Sep-10	Final Rpt Sept 2010-Summary.xls
Revenue Forecast	Dave Kavannaugh, ODOT	Oct-10	VMT Forecast for HCAS_2011 Final Table.xls, Table 1 FSB Estimation Methode HCAS Forecast.xls
Revenue Forecast	Dan Porter and Lani Pennington, ODOT	Nov-10	Revenues 2011-13_Carl.xls
RUAF Collection reports	Lani Pennington, ODOT	Sep-10	MCT_OD_P_RUAFRPT.csv, MCT.OD.P.RUAFRPT_09.csv, MCT.OD.P.RUAFRPT.txt
Special Weighings	Rick Munford, ODOT	Jul-10	Truck Weigh 2009.xls, Truck Weigh 2010.xls
Transit VMT: Lane Transit District	George Trauger, LTD	Sep-10	Fleet Maintenance Weights and Miles_2009.pdf
Transit VMT: Tri-Met	Kurtis McCoy, TriMet	Sep-10	fleet data.xlsx
WMT Collection Reports	Lani Pennington, ODOT	Sep-10	WMT data fields.xls, HUS_Example.xls, weight mile.out, WM_Final.csv
Weigh-In-Motion Data	Chris Monsere, Portland State University	Jun-10	transponder_list.csv, wim_truck_data2009.csv, wim_stations.csv
Automatic Traffic Recorder Data	Chris Monsere, Portland State University	Jun-10	loopdata_5min_2009.csv, portal_detectors.csv, portal_highways.csv, portal_stations.csv

Processing of Original Data

The following section provides the SQL codes for the data sets requiring pre-processing outside of the HCAS model. Due to the complexity of the data tabulations and calculations or the sheer size of the data sets, these data transformation/summary tables were created in a database program which the output summary tables from these transformations pasted into the appropriate workbook tabs.

DMV Registration Data

DMV registrations by weight class and tax class are used to estimate the BaseVMT (base year VMT) in the *DMV-Other* tab in the Base VMT workbook. The following SQL code was used to process the raw DMV Registration data. The plate numbers were used to determine the tax class and the veh_weight variable was used to assign the weight class. With the exception of exempt (E), buses (B), and school buses (SC) whose registrations do not necessarily expire, the data were filtered using the expiration date. The "Fuel" column may also be labeled "Power."

```
ALTER TABLE dmv_registrations ADD COLUMN expired boolean;
ALTER TABLE dmv_registrations ADD COLUMN weight_class int4;
update dmv_registrations set weight_class =
int8((cast(veh_weight as int4)-1)/2000)*2000 + 1;

ALTER TABLE dmv_registrations ADD COLUMN tax_class varchar(255);
update dmv_registrations set tax_class=
CASE
when substr(plate,1,1)='B' and substr(plate,2,1)<'A' then 'B'
when substr(plate,1,1)='E' and substr(plate,2,1)<'A' then 'E'
when substr(plate,1,2)='SC' and substr(plate,3,1)<'A' then 'SC'
when substr(plate,1,2)='CN' and substr(plate,3,1)<'A' then 'CN'
when substr(plate,1,1)='F' and substr(plate,2,1)<'A' then 'F'
when substr(plate,1,2)='HC'and substr(plate,3,1)<'A' then 'HC'
when substr(plate,1,2)='HF' and substr(plate,3,1)<'A' then 'HF'
when substr(plate,1,2)='PF' and substr(plate,3,1)<'A' then 'PF'
when substr(plate,1,1)='T' and substr(plate,2,1)<'A' then 'T'
when substr(plate,1,2)='TW' and substr(plate,3,1)<'A' then 'TW'
else 'other'
End;

select tax_class, fuel, weight_class, count(plate) as vehicles
from dmv_registrations
where not expired or tax_class in ('E', 'SC', 'B') and fuel!='6'
group by tax_class, weight_class, fuel
order by tax_class, weight_class, fuel;
```

DMV Motor Home Registrations

Motor home VMT were estimated using motor home vehicle counts from the DMV data with an assumed annual VMT. Weights are not included for motor homes in the DMV data so the vehicle length (in feet) is used with motor home manufacturer's data on vehicle lengths and weights to assign the motor home vehicle counts to weight classes. The SQL code processes the DMV data to create a table of motor home registration counts by vehicle length.

```
select tax_class, fuel, weight_class, veh_length, count(plate) as vehicles
from dmv_registrations
where not expired and tax_class in ('HC') and fuel!='6'
group by tax_class, fuel, weight_class, veh_length
order by tax_class, fuel, weight_class, veh_length;
```

WMT Collections

The SQL code for the WMT Collection reports data first create the weight_class and axle_count variables and then create the WMT summary table, which is pasted into the *WMT* tab in the Base VMT workbook.

```
ALTER TABLE wmt_payments ADD COLUMN weight_class float;
ALTER TABLE wmt_payments ADD COLUMN axle_count int;

UPDATE wmt_payments SET
        weight_class = TRUNC((weight - 1) / 20) * 2000 + 1,
        axle_count = CASE WHEN weight < 801 THEN 0 WHEN axle > 9 THEN 9 WHEN axle<5 THEN 5
                ELSE axle END;

SELECT weight_class, axle_count, SUM(miles) AS miles
FROM wmt_payments
GROUP BY axle_count, weight_class
ORDER BY axle_count, weight_class;
SELECT weight_class, axle_count, SUM(miles) AS miles  FROM wmt_payments  GROUP BY
        axle_count, weight_class ORDER BY axle_count, weight_class;
```

Open up the Base VMT workbook and paste the WMT summary table into the *WMT* tab.

Flat Fee Collection Reports

In previous studies, the cleaned Flat Fee Reports were obtained in a raw, database (ascii or text) format. In the 2011 Study, Flat Fee Reports were provided in a series of tabs/tables in an Excel workbook. Given that the Flat Fee data were already in Excel, there was no need to read the Flat Fee Reports into a database and run SQL queries.