APPENDIX

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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 Transporation 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).

AMT: See Axle Miles of Travel

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

ATR: See Automatic Traffic Recorder

Automatic Traffic Recorder: A device that records the number of vehicles passing a point on a road. May be permanent or temporary, may record individual lanes separately, may identify vehicle configurations, and may also record vehicle speeds.

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 expend- itures 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 principaland 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.

ESAL: See Equivalent Single Axle Load

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.

FHWA: Federal Highway Administration, an agency within the US Department of Transportation that supports State and local governments in the design, construction, and maintenance of the Nation's highway system.

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.

HCAS: See Highway Cost Allocation Study

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.

HPMS: See Highway Performance Measurement System

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.

MCTD: See Oregon Motor Carrier Transportation Division

NAPCOM: See National Pavement Cost Model

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.

ODOT: Oregon Department of Transportation

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

Oregon Motor Carrier Transportation Division: A division within the Oregon Department of Transportation that regulates commercial trucking within the state.

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.

PCE: See Passenger Car Equivalent

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.

SRT: Study Review Team

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.

VMT: See Vehicle Miles of Travel

Weigh in Motion: A device embedded in the roadway that captures the weight of each axle passing over it. May also record transponder IDs of transponder-equipped trucks, axle spacing, and speeds.

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.

WIM: See Weigh in Motion

INTRODUCTION

This document summarizes three highway cost allocation studies (HCAS) published during 2009 to 2023: Nevada 2009, Idaho 2010, and Minnesota 2012. This review of recent HCAS is intended to investigate HCAS processes and methods used in other states, with particular attention paid to innovations, issues, or other methodologies or data that might be of use or interest for the Oregon HCAS process. The document also summarizes the findings from recent papers and reports on HCAS methods.

SUMMARY

Overview of HCAS Studies

2009 Nevada Highway Cost Allocation Study

The Nevada HCAS used the FHWA State HCAS software and methodology, conducted the study using ten vehicle classes (based on the HPMS vehicle classes), and presents equity ratios for vehicle weight using 2,000 lb. increments. The study included revenues from the vehicle sales tax and ad valorem tax for passenger vehicles. As a result, total state revenues were roughly 75% higher than total state expenditures in calculating the unadjusted state equity ratios.

Inclusion of revenues that are diverted to non-highway increases the revenue shares for passenger vehicles. Two other unique aspects of the study are the inclusion of deferred maintenance costs for vehicle cost responsibility and the subtraction of federal stimulus funding from deferred maintenance. The study found that heavy vehicle user fees do not increase as fast as heavy vehicle cost responsibility. Light vehicle classes have equity ratios greater than 1.0 and heavy vehicles have equity ratios less than 1.0.

2010 Idaho Highway Cost Allocation Study

The report considers the equity of Idaho's tax structure for highway users and whether different vehicle classes are paying their proportional share of highway costs. The Idaho HCAS used a refined version of the FHWA State HCAS Model. The model was used to consider how adjustments to the current tax and fee structure and the implementation of a vehicle miles travelled (VMT) fee could affect equity ratios.

The study differentiates user classes by vehicle class and weight for a total of 20 user classes. For state and federal programs combined, the study finds that highway user payments fall short of expenditures by 20% ($139.5 million per year). The study also finds that when collections from state and federal programs are combined, payments from combination trucks fall short of cost responsibility by 33%, whereas payments from automobiles exceed cost responsibility by 47%. At a state level, similar results hold, with combination trucks' payments falling 27% short of cost responsibility and automobiles' payments exceeding cost responsibility by 26%.

Minnesota Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees, 2012

The report examines the pros and cons of different highway cost allocation methods to use in Minnesota and presents a methodology that is most appropriate for the conditions in Minnesota. The report first presents the results of using the State HCAS tool developed by the FHWA. The report then develops and presents the results from a HCAS that was customized for the state, Minnesota Highway Cost Allocation Tool (MHCAT). The report also presents the findings from experiments on auction-based permitting systems.

Oregon's HCAS and Differences with Other States

Cost-Occasioned Approach and Incremental Method

Oregon, in addition to other states, uses the cost-occasioned approach for its HCAS. The basic idea behind this approach is that each class of road user should pay for the road system in proportion to the costs associated with the road use by that class.

Within the cost occasioned approach, Oregon uses the incremental method. This method divides particular aspects of highway costs into increments. It allocates the costs of successive increments to only the vehicles needing the higher cost increment.

A primary example of the incremental method is with bridge allocation costs. The first increment for a new bridge identifies the cost of building the bridge to support its own weight and other non-load related stresses. This is a common cost responsibility, and allocated across vehicle classes on basis of each user class's share of total VMT. The next increments identify the additional cost of building the bridge to accommodate progressively heavier weight classes of vehicle and the costs are allocated on the basis of relative VMT within a truncated range of vehicle weight classes.

Oregon's Weight Mile Tax

A key difference between Oregon and other states is that Oregon implements a weight mile tax in addition to a fuel tax. The Federal FHWA HCAS tool does not support a weight mile tax. Oregon has developed its own HCAS tool that supports a weight mile tax. The weight mile tax is structured in terms of 2,000 pound increments.

Oregon's use of a weight mile tax means that it is able to achieve much better equity ratios. Without a weight mile tax, a state would have to rely on high truck registration fees since the fuel tax alone does not recover the damage to roads imposed by heavy trucks. As vehicle weights increase, the damages imposed to roads increases super-linearly, but fuel consumption increases sub-linearly. This means that as vehicle weights increase, the costs they impose on the road are increasingly higher than the amount of fuel taxes they pay. The inclusion of a weight mile tax allows the State to capture the higher costs from heavier vehicle weights.

It is interesting to note that the 2012 Minnesota report examines the hypothetical effects of including a weight-mileage fee where the user pays a usage fee based on vehicle miles traveled and the tax rate per mile is determined by the registered gross weight of the vehicle. Currently, Minnesota charges only a weight fee that is determined by a commercial vehicle's RGW (e.g., a registration fee). The report finds that adjusted equity ratios under both hypothetical weight-mile fee scenarios are closer to the target ratio (one) than the weight fees for most vehicle classes. Exhibit 2 (p. 105) shows the adjusted ratios at the state level for the weight fees and the weight-mile fees.

Other Differences

- Oregon uses 2,000 pound increments in its HCAS whereas most other states use 5,000 pound increments. This allows Oregon's HCAS to have a finer grain of analysis than other states.
- Oregon, Nevada, and Idaho use the National Pavement Cost Model (NAPCOM) for pavement costs. However, Oregon has modified NAPCOM to use 2,000 pound increments instead of 5,000 pound increments. The 2012 Minnesota report uses regression coefficients from NAPCOM for Minnesota to allocate pavement repair costs.
- Oregon uses different PCE VMT (regular and congested) allocators depending on the type of cost. For example, the common cost portion of projects that add highway capacity are allocated based on congested PCE VMT. Congested PCE VMT uses the shares of PCE-weighted VMT that are present during the most congested hour of the day on that functional class. Using congested PCE VMT in cases where costs are incurred to add capacity means that a portion of those costs is allocated based on the users that are driving the need for additional capacity.
- Unlike Nevada's 2009 HCAS, Oregon's HCAS does not include deferred maintenance. Oregon has looked at deferred maintenance when determining an efficient fee. However, Oregon does not include deferred maintenance in its HCAS because it has very well-defined costs that are within the upcoming biennium.
- Oregon includes a studded tire adjustment that takes into account the additional damage that they cause to the roads.
- Oregon uses truncated VMT allocators for different types of costs to allocate those costs to a subset of all vehicles. For example, the collection costs of the motor carrier Transportation Division are allocated on the basis of VMT for vehicles over 26,000 pounds.
- Oregon's adjusted equity ratios reflect adjustments for subsidized vehicles. In contrast, Nevada's adjusted equity ratios do not consider subsidized vehicles and instead are calculated based on share of revenue and cost responsibility share, rather than gross dollar amounts.
- Exhibit 4 (pp. 17-18) provides a high-level overview of different states' HCASs. The table provides information on the states' HCAS methods, key allocators, types of revenue examined, and cost responsibility for heavy vehicles.

Overview of HCAS Methods

Models for Highway Cost Allocation, 2013

The report reviews the traditional HCAS methods (incremental, proportional, or a combination of the two), and then presents an alternative, non-traditional HCAS method that is based on concepts from the theory of cooperative games.

A Road Pricing Methodology for Infrastructure Cost Recovery, 2010

The broad motivating question for the report is: How can governments equitably recover infrastructure costs from truck users based on real-time operations and individual vehicles? The report presents a framework for charging commercial vehicles using weigh-in-motion (WIM) systems.

Bridge Structure Comparative Analysis, Comprehensive Truck Size and Weight Limits Study, 2013

This study provides a list of agencies that provide technical support through research, ongoing studies, and practice. The study provides a list of documents that the study reviewed with short summaries. A number of the documents address the issue of how to recover costs from heavy vehicles in proportion to the damage they cause on bridges.

State Highway Cost Allocation Studies: A Synthesis of Highway Practice

This report is intended to help states with HCAS methods by laying the foundation on current HCAS methods and areas of improvement for HCAS methods. The report reviews the HCAS methods used by different states, the conceptual foundation of HCAS methods, methods for revenue attribution, and arising issues with HCAS methods.

HCAS BY OTHER STATES

2009 Nevada Highway Cost Allocation Study

The 2009 Nevada HCAS used a refined version of the 1997 FHWA State HCAS program (HCASP). The study covers the eight-year time horizon between 2009 and 2016. Ten vehicle classes (auto, bus, and eight single unit or tractor trailer truck classes) are used, based on the twelve HPMS vehicle classes. Equity ratios are tabulated by vehicle class and also by registered vehicle weight (using 2,000 lb. increments).

The 1999 Nevada HCAS adopted many of the recommendations from the 1994 audit of the Nevada HCAS process. Two additional recommendations were adopted in the

2009 HCAS:

- The use of more vehicle classes. Previously only basic and heavy vehicle classes were differentiated for reporting purposes.
- Inclusion of highway user fees that are diverted to non-highway uses (e.g., inclusion of federal highway funds diverted to mass transit and inclusion of state vehicle sales tax and ad-valorem tax revenues which are diverted to general fund).

Nevada calculates unadjusted and adjusted equity ratios. Unlike Oregon, Nevada's adjusted equity ratios do not reflect subsidized vehicles. Rather, Nevada's adjusted equity ratios are calculated based on share of revenue and cost responsibility share, rather than gross dollar amounts.

The primary difference between the equity ratios in the 1999 Nevada HCAS and 2009 Nevada study is the inclusion of revenues from the vehicle sales tax and the ad valorem (government service) tax. Another difference in the 2009 study from previous Nevada DOT studies is the use of the improved NAPCOM model and more accurate weigh-in-motion (WIM) data for operating weights of heavy vehicles.

Nevada DOT data sources were used when available for calculating revenue, determining future VMT, and determining expenditure classifications. The VMT forecast is based on the Nevada DOT VMT forecast and is validated by applying an assumed per-person annual mileage to Nevada's forecasted population growth rate. There is no mention of differentiating VMT growth rates by vehicle class, although there is some discussion of per person mileage in rural versus urban areas of the state.

Revenue Attribution

The Nevada HCAS includes both federal and state revenues, and also includes all revenue sources regardless of their use (e.g., includes highway revenues diverted to non-highway purposes). As a consequence of including the vehicle sales tax and ad valorem tax, state revenues are forecast to exceed state highway expenditures by 75%. The study notes that this difference is "counterbalanced" by local expenditures, which exceed local user payments (since the state and local governments direct a portion of general funds to local roadways).

Cost Responsibility

Assignment of expenditures to work categories is based on previous expenditures, funded projects data (e.g., STIP, etc.), and trends in project expenditures. In addition to funded future expenditures, the Nevada HCAS also includes estimates of deferred pavement and bridge preservation for allocation of system preservation costs. Nine project work types, covering the typical project categories for pavement, bridges, maintenance, preservation, etc., were used to classify highway expenditures.

Nevada received $201 million in federal stimulus funding, of which $130 million is deducted from the backlog of preservation and the remaining ($71 million) is applied to projects along the National Highway System and urban projects in the STIP. The forecast of future expenditures was developed using recent trends in expenditures and anticipated revenues and consultation with NDOT. Projects were assigned work types based on recent year expenditures and programmed expenditures in the STIP. The FHWA State HCAS Model was used to estimate cost responsibility by vehicle class using the categorized expenditures and allocators for each type of expenditure. Cost allocation by work type is summarized based on the information in the HCAS report:

Pavement cost responsibility is determined using NAPCOM and vehicle class weight distributions developed from weigh-in-motion data. New bridge construction costs were allocated based on an incremental method, as applied in the FHWA HCASP model.

- Bridge replacement costs were allocated based on the replacement attributed to deficient load-bearing capacities relative to total degradation using the FHWA Bridge Sufficiency Rating formula.
- Bridge rehabilitation costs were apportioned based on determining the share of load-related costs relative to all costs based on a sample of bridge repair projects and default values from the FHWA's Bridge Needs and Investment Process.
- DMV expenditures related to the Motor Carrier Program were allocated to heavy vehicles, based on heavy vehicle VMT. The remaining DMV expenditures are allocated across all vehicle classes, based on shares of travel.
- Department of Public Safety expenditures include the State Emergency Response Commission (SERC), which responds to highway incidents. Heavy vehicles are allocated half of the SERC costs, based on the rationale that heavy vehicle crashes are more severe and require more time and expense to clear. The remaining DPS expenditures are allocated based on shares of travel.
- Administrative and overhead costs are allocated to vehicle classes in the same proportion as the sum of the capital and maintenance programs.
- Bond expenditures, both capital expenditures and debt service, are allocated in the same proportion as capital expenditures on urban interstate systems where the bond-financed projects are located.

Equity Ratios and Findings

The study results are presented as unadjusted and adjusted equity ratios for each vehicle class and by registered gross vehicle weight. Unadjusted equity ratios are constructed as the ratio of gross (dollar amounts) revenues to expenditures from each vehicle class. Adjusted equity ratios are constructed as the ratio of the vehicle class share of revenues to share of expenditures.

As a result of the inclusion of the state vehicle sales tax and ad valorem taxes, state revenues exceed state expenditures. This results in an "overpayment" of highway revenues compared to expenditures and produces a total unadjusted equity ratio for state-only revenues and expenditures of 1.75, reflecting that state revenues exceed state expenditures by 75%.

The effect of including revenues used for non-highway purposes is partially obscured by the inclusion of deferred maintenance and the subtraction of federal stimulus dollars from those deferred preservation expenditures. Excluding vehicle sales tax and ad valorem tax revenues from the total state revenues increases the adjusted heavy vehicle class share of state revenues to 31.1% from 18.9%. The heavy vehicle adjusted equity ratio goes from 0.42 up to 0.74 (state revenues and expenditures only) when these non-highway revenues are excluded.

The findings from the study suggest that Nevada's heavy vehicle fee structure does not increase proportionally with registered weight; hence heavy vehicles tend to underpay. Only vehicles less than 8,000 lbs. have an adjusted equity ratio of 1.50. This is consistent with the findings from other states' HCAS.

2010 IDAHO HIGHWAY COST ALLOCATION STUDY

The report considers the equity of Idaho's tax structure for highway users and whether different vehicle classes are paying their proportional share of highway costs. The 2010 Idaho HCAS used a refined version of the FHWA State Highway Cost Allocation Tool (HCAT). The HCAT was used to consider how adjustments to the current tax and fee structure and the implementation of a vehicle miles travelled (VMT) fee could affect equity ratios.

Two factors affecting the 2010 Idaho HCAS include the repeal of the weight-distance tax in favor of a mileage-based registration fee system and the types of projects that are funded by the Grant Anticipation Revenue Vehicle (GARVEE) bonds influence the equity ratios in the report. Idaho issued GARVEE bonds that are backed by federal aid to advance its construction program. The GARVEE bond program affects the cost allocation, as a higher portion of expenditures are pavement-related, which in turn affects the cost responsibility for heavy trucks. Under the reduced GARVEE scenario, expenditures are equal to the annual debt service payments during the six-year time period.

The study uses 20 vehicle classes. Vehicle classes are differentiated by vehicle type and weight. The study has a six-year time period from 2007 to 2012. The study considers three levels of government: state, federal, and local expenditures and revenues. Travel and expenditure data are broken down by rural and urban highway functional classes. Rural includes interstate, principal arterials, minor arterials, major collectors, minor collectors and local. Urban includes interstate, principal arterials, minor arterials, collectors and local. Travel data includes total vehicle miles traveled by the 20 vehicle classes and 11 functional road classifications.

Key findings from the Idaho HCAS include:

- Highway user payments fall short of expenditures by 20% ($139.5 million per year) for state and federal programs combined.
- With state and federal programs combined, combination trucks' payments fall 33% short of cost responsibility (28% under reduced GARVEE scenario), whereas automobiles' payments exceed cost responsibility by 47% (38% under reduced GARVEE scenario).
- Considering state programs alone, combination trucks' payments fall 27% short of cost responsibility (14% under reduced GARVEE scenario), whereas automobiles' payments exceed cost responsibility by 26% (8% under reduced GARVEE scenario).

Revenue Attribution

Revenue data include state and federal historical data from 2007 to 2009 and revenue forecasts based on Idaho Transportation Department (ITD) forecasts from 2010 to 2012. Revenue data include receipts from highway users from the tax and fee structure (e.g., registration fees, motor fuel taxes, driver's license fees, permit fees, and title fees).

The study obtained federal revenues that are attributable to highway users in Idaho for 2008 and 2009 from FHWA 2009 Highway Statistics. The FHWA estimates were forecast forward until 2012 using the revenue forecasts prepared by ITD. The federal tax revenue estimates reflect what Idahoans pay into the Federal Highway Trust Fund.

The study attributed revenue to the 20 vehicle classes and to registered gross weight classes in 2,000 lb. increments above 8,000 lbs. Some of the default data estimates in the FHWA HCAT were replaced with Idaho-specific inputs. The study worked with the ITD and other data sources to estimate the following characteristics for each vehicle class: VMT, percentage of VMT outside of Idaho, MPG, and number of registered vehicles. This allowed tax revenue to be attributed to each vehicle class. Fuel tax revenues were attributed by vehicle class based on the VMT estimates and the vehicle class's MPG. Revenues from registration fees were attributed based on the breakdown of fees by vehicle class (passenger vehicles, trucks, and buses). The study also estimated the number of full fee equivalent vehicles by registered weight class based on total VMT and the average VMT per vehicle estimates.

Cost Responsibility

The study uses expenditure data for nine categories: new pavements, rehabilitated pavements, new bridge, replacement bridge, repair bridge, grading, other construction, maintenance, and administration and other expenditures. Expenditure data were obtained for capital expenditures from ITD for the 2007-2012 time period.

The study estimated cost responsibility for each vehicle class using the FHWA HCAT. Idaho updated the FHWA HCAT to reflect Idaho's highway system and vehicle use. The study used weigh-in-motion (WIM) data to refine weight-related HCAT model inputs. The study used a recent FHWA run of the National Pavement Cost Model (NAPCOM) with 2007 highway section data from ITD. The study uses bridge cost allocation procedures developed by the FHWA in the Federal HCASs in 1982 and 1997.

Travel Data

The study derived VMT data by functional road class and by vehicle class using vehicle classification data from 2004-2008, breakdowns of VMT by functional class from 2008 and 2009, and weigh-in-motion (WIM) data from 2008 and 2009 from ITD. The Idaho Highway Performance Monitoring System (HPMS) has 12 vehicle classes but the FHWA HCAT uses 20 vehicle classes. Idaho used the two years of WIM data to map the 12 HPMS vehicles classes estimated from the classification count data into the 20 vehicle classes. WIM data were only provided for three functional classes: rural interstate, rural principal arterial, and rural minor arterial. The study had to make further assumptions on how to apply the vehicle splits to other roads.

Equity Ratios and Findings

The Idaho HCAS reports the unadjusted and adjusted equity ratios for the state level as well as the state and federal levels combined. Similar to HCAS in other states, as registered gross weights increase, equity ratios decrease.

One particularity of the Idaho HCAS is the GARVEE bond program. The GARVEE bond program affects the cost allocation, in that a much higher proportion of highway funds are directed toward pavement expenditures. Since most pavement costs are a result of the impact of heavy trucks, the bond program significantly increases the cost responsibility to heavy trucks (in particular, trucks with 12,000-18,000 lbs. per axle or 28,000-34,000 lbs. per pair of axles).

The researchers performed a sensitivity analysis to explore the effects of the GARVEE program on the HCAS findings. The researchers considered the scenario where expenditures are equal to the annual debt service payments during the 2007-2012 time period. The annual debt service payments over the six years are approximately equal to 26% of the GARVEE bond expenditures over the same time period. In the reduced GARVEE bond scenario, construction expenditures decrease by $96.9 million. Under this scenario, adjusted equity ratios increase for combination trucks and decrease for automobiles. On the state level, there is a greater difference in results between the two scenarios than on the level where state and federal are combined. On the state level, the adjusted equity ratio for automobiles drops from 1.26 to 1.08 under the reduced GARVEE scenario and increases for combination trucks from 0.73 to 0.86.

The other notable change for Idaho was the repeal of the weight-distance tax on trucks in favor of a mileage-based registration fee system in 2001. According to the study, if the weight-distance tax had remained in place, revenues were forecast to increase to $60.4 million in 2008 (based on analysis of historical trends).

Instead, under the mileage-based registration fee system, revenues were $48.8 million in 2008 ($11.6 million lower than the forecasts under the weight-distance tax).

Policy Analysis

The Gubernatorial Task Force on Modernizing Transportation Funding evaluated 19 possible sources of revenue. They considered eight criteria in their evaluation: fairness, public acceptance, revenue predictability, trend (up or down), cost-effectiveness of implementation, readiness, competitiveness, and out-of-state equity. The top ten revenue sources are (from highest to lowest): fuel tax of 5 cents per gallon, fuel sales tax, index fuel tax, state truck registration fee, index passenger vehicle registration fee, county vehicle registration fee, sales tax on auto sales, parts, tires and accessories, weight distance tax, electric vehicles, and alternative fuels tax.

The study examines the equity impacts from seven different policy options. The seven policy options are listed below along with their outcomes on equity (equity ratios are for the state and federal levels combined):

1. **Gasoline and special fuel tax rates increase by 5 cents per gallon.** Revenues forecast to increase by $46.2 million annually. Tax falls on passenger vehicles and trucks equally, and there is little change in adjusted equity ratios.
2. **Gasoline tax rate increases by 5 cents per gallon.** Adjust the special fuel tax rate such that the equity ratio for vehicles with RGWs of over 26,000 lbs. is equal to one. Revenues forecast to increase by $307.6 million annually. Equity ratios improve across vehicle classes (move closer to one). Adjusted equity ratios for automobiles and DS8+ change from 1.47 to 1.06 and 0.49 to 0.67, respectively.

3. **Special fuel tax rate increases by 5 cents per gallon, and gasoline tax rate adjusts to the level needed to achieve equity.** Revenues forecast to decrease by $147.0 million annually. Equity is almost realized between broad vehicle classes (between vehicles above and below 26,000 lbs.).
4. **All vehicle registration fees increase by 10%.** Revenues forecast to increase by $11.6 million annually. Fees are applied to all vehicle classes, and have almost no effect on equity.
5. **Passenger car vehicle registration fees increase by 10% and heavy truck registration fees increase by level needed to achieve equity.** Revenues forecast to increase by $165.8 million annually. Heavy truck registration fees would need to increase by a factor of 4.07 to achieve equity. Equity would be achieved between light and heavy vehicle classes. However, payments from heaviest vehicle classes would still fall short of cost responsibility by up to 45%.
6. **Heavy truck registration fees increase by 10% and passenger car vehicle registration fees increase by level needed to achieve equity.** Revenues forecast to decrease by $47.7 million annually. Passenger car (light vehicle) registration fees would be eliminated. Equity would improve with the automobiles adjusted equity ratios decreasing from 1.47 to 1.38.
7. **Vehicles over 26,000 lbs. RGW pay a VMT tax.** Revenues forecast to increase by $81.9 million annually. VMT fees are around 5.3 cents per mile for vehicles with RGW of 80,000 lbs. and 11.1 cents per mile for RGW of 105,500 lbs. Equity ratios for heavy vehicles improve significantly. The adjusted equity ratio for the DS8+ vehicle class would increase from 0.49 to 0.85. For the LT4 vehicle class, the adjusted equity ratio would decrease from 1.18 to 1.03.

2012 Minnesota Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees

Minnesota conducted an HCAS in 2009 that used the FHWA's State Highway Cost Allocation Tool (HCAT), relying on some national default data and state specific data when it was available. In 2012, the Minnesota Department of Transportation (MnDOT) and the University of Minnesota developed a customized highway cost allocation tool for Minnesota based on the FHWA's tool, and compared the results of the customized tool to the results from the general tool. The report also presents the findings from the HCAS using the FHWA HCAT that are using the same methods as the 2009 HCAS (see 2009 Minnesota HCAS summary at the end of the paper after References).

In the 2012 HCAS, Minnesota compares the results from the FHWA HCAT and a customized tool for MnDOT, Minnesota Highway Cost Allocation Tool (MHCAT). MHCAT fixes known bugs in the FHWA HCAT and is intended to work with Minnesota-specific data. The FHWA HCAT does not allow certain tax revenues (e.g., registration and weight fees) to be attributed to a specific subset of vehicle classes. Additionally, the FHWA HCAT does not correctly allocate administrative costs associated with the collection of registration and weight fees.

Another issue the study found was that the registered gross weight breakdowns or the vehicle configurations are based on representative data from 2001. Furthermore, the mapping of the 12-vehicle configurations to the 20-vehicle configurations is based on national VMT data from 1997.

MHCAT classifies vehicles according to Highway Performance Monitoring System, (HPMS) 12-class whereas FHWA HCAT classifies them according to HCA 20-class. Without a customized tool, use of the FHWA HCAT requires mapping the HPMS classification onto the HCA classification (as in the case of the 2010 Idaho HCAS and the previous 2009 Minnesota HCAS). The customized tool removes unnecessary data manipulation and increases accuracy. MHCAT also allows the user to enter up to eight customized vehicle classes. This is a useful tool for research purposes, such as considering specific changes to tax rules and cost allocation for specific vehicle classes.

The FHWA HCAT cannot allocate external costs such as environmental impacts, congestion, and accident costs. External costs are a result of highway use, and can be significant. However, they are difficult to include into the HCAT since they are dependent on the time of travel and route selected, and they do not depend solely on the type of vehicle and VMT. This is not an issue that is resolved in the MHCAT.

The report also evaluates the HCAS methods, with particular emphasis on tax equity (vertical and horizontal) and efficiency. In particular, the report compares a fuel versus a weight-distance tax using a stylized mathematical model.

The results support that a weight-distance tax or other mileage-based tax that can be differentiated by truck class can help achieve a more equitable tax policy than a universal fuel tax. However, the examples presented also indicate that equity can be improved if the universal tax encourages the truck industry to use trucks that cause less damage. The alternative is to achieve equity through a tax policy that differentiates by truck class and truck usage.

The report lists two categories with two options in each category as directions for future research that are associated with the equity and efficiency of the road-use tax structure.

- Mileage-Based Taxation: This can be implemented using a comprehensive *Electronic Road Pricing System (ERPS)* or a *weight-distance tax system*.
    - With an *ERPS*, tax rates can be set based on vehicle type, vehicle weights, number of axles, congestion levels, and the road conditions for the individual trip.
    - *Weight-distance taxes* are charged based on the vehicle's registration weight, distance travelled, and axle configuration.
- Special Permits and Willingness-to-Pay: The state currently issues special permits to oversized or overloaded trucks, but there is a need for a better pricing mechanism. Options to improve the pricing mechanism include:
    - Estimating *Willingness-to-Pay (WTP)* using contingent valuation.
    - Implementing an *auction-based permitting system (ABPS)*.

Minnesota Department of Transportation (MnDOT) provided revenue and expenditure data and traffic data for the 2003-2007 time period. MHCAT, like HCAT, requires pavement parameters, bridge parameters, and vehicles' features and travel-related data. The inputs are in nine different Excel tabs in the MHCAT workbook. Default bridge parameters are imported from HCAT but can be modified to reflect the state's conditions through assistance from the state engineer. The report uses VMT numbers from MnDOT that represent an average from 2004 to 2007.

The workbook requires registered gross weight distributions by vehicle class by 2,000 lb. increments from 8,000 lbs. to 152,000 lbs These data were obtained from the Vehicle Inventory and Use Survey from 2002 (VIUS 2002) collected by the U.S. Census Bureau. The default data for MPG by vehicle class and RGW, the average annual distance travelled by vehicle class, and the distribution of vehicles by fuel type are all from VIUS 2002. Axle weight distribution data are from WIM systems from 2006.

Revenue

The MHCAT includes both federal and state revenues. At the federal level, inputs include fuel taxes, heavy vehicle use tax, vehicle sales taxes, and tire taxes. At the state level, inputs include fuel taxes, weight fees (only applicable to trucks), registration fees (passenger vehicles and light trucks), vehicle sales taxes, and permit fees.

Expenditures

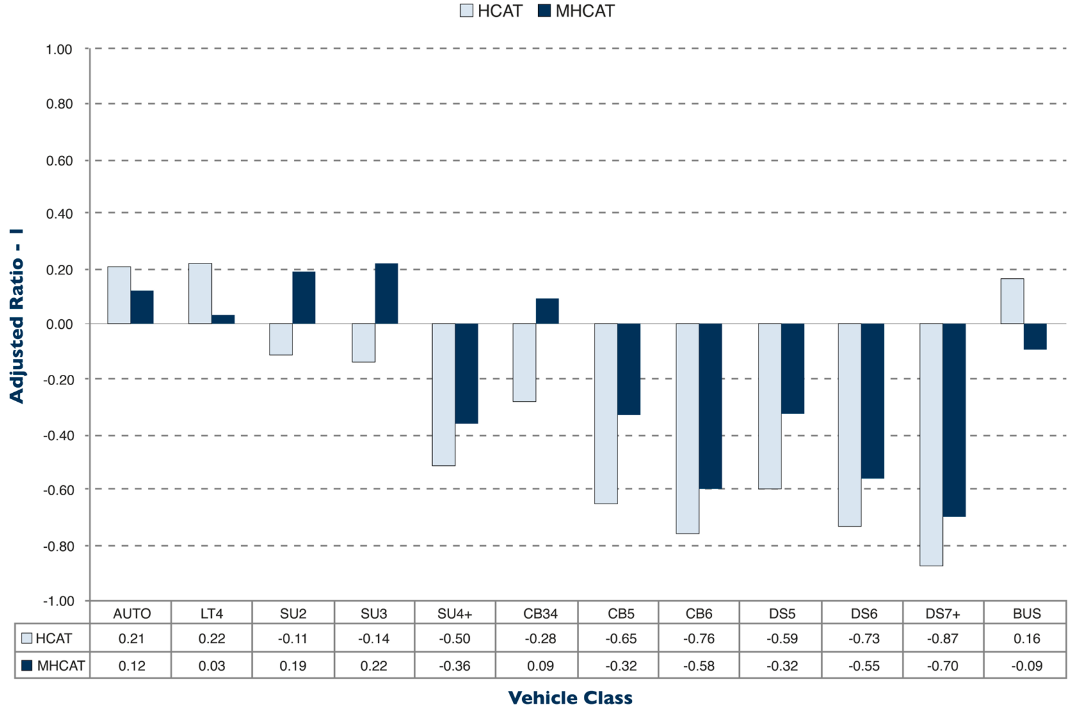
MHCAT inputs related to expenditures are categorized into six parts: state level construction and maintenance, state level administration, state-aid administration, state aid construction and maintenance, federal-aid administration, and federal-aid construction and maintenance. Each part requires expenditures disaggregated by highway functional class for 25 categories. The categories include typical highway project categories such as pavement (new, repair, etc.), bridge (new, replacement, rehabilitation), and maintenance and administrative categories. MHCAT includes the costs of collecting user fees on fuel, which are assumed to be zero by many states.

The default inputs on how non-load-related expenditures are allocated are based on FHWA HCAT. These include grading, residual allocators, other costs, and systemwide and DMV costs. The user can specify the percentage of grading costs by vehicle weight. For residual allocators, other costs that are distributed by highway functional class, and systemwide costs and DMV administration costs, the user can specify VMT or PCE-VMT, or a fraction between 0 and 1 (e.g., 0.3 means that 30% is allocated based on VMT and 70% is allocated based on PCE-VMT).

Equity Ratios and Findings

The report compares the equity ratios obtained from FHWA HCAT and MHCAT. It considers the difference between the adjusted equity ratios from the two tools to the target ratio (one). Like the 2009 Nevada HCAS, unadjusted equity ratios are constructed as the ratio of gross (dollar amounts) revenues to expenditures from each vehicle class. Adjusted equity ratios are constructed as the ratio of the vehicle class share of revenues to share of expenditures.

EXHIBIT 1.
HCAT (FHWA) AND MHCAT: ADJUSTED RATIOS MINUS TARGET RATIO (ONE), STATE REVENUE AND EXPENDITURES ONLY



In general, the equity ratios from MHCAT are less extreme than those from FHWA HCAT. Exhibit 1 shows the differences between the ratios for FHWA HCAT and MHCAT by vehicle class. The report attributes some of the differences to the fact that RGW, OGW, and axle distributions are based on Minnesota specific data in MHCAT, as opposed to national averages in the FHWA HCAT.

The report finds that automobiles, light trucks, and single-unit trucks (three axles or less) have equity ratios greater than one. The report also finds that all combination trucks (except for single trailer with four or fewer axles) have adjusted equity ratios less than one. As is the case in other states' HCASs, the study indicates that heavy trucks are not paying taxes in proportion to the damage they cause to road infrastructure.

Effects of a Weight-Mileage Fee

Currently, Minnesota charges a weight fee that is determined based on a commercial vehicle's RGW (e.g., a registration fee). The report examines the effects of including a weight-mileage fee where the user pays a usage fee based on vehicle miles traveled and the tax rate per mile is determined by the registered gross weight of the vehicle. The report considers two scenarios. The first scenario assumes that total revenues from trucks are not changed (Minnesota collects $98 million from the weight-mileage fee). The second scenario assumes that the state collects $160 million from the weight-mileage fee (the amount of load-related expenditures (pavement and bridge) allocated to trucks). The study estimates the cost per mile for each vehicle-RGW class and then sets the tax rate to be proportional to the estimated cost.

EXHIBIT 2.
ADJUSTED EQUITY RATIOS FOR WEIGHT FEES (RGW REGISTRATION FEE) AND WEIGHT-MILE FEES, STATE

VC	Weight Fees	W-M Fees (Scenario 1)	W-M Fees (Scenario 2)
AUTO	1.12	1.12	1.08
LT4	1.03	1.03	1.00
SU2	1.19	0.89	0.86
SU3	1.22	0.89	1.00
SU4+	0.64	0.67	0.80
CB34	1.09	0.95	1.07
CB5	0.68	0.75	0.88
CB6+	0.42	0.57	0.71
DS5	0.68	0.81	0.93
DS6	0.45	0.63	0.77
DS7	0.30	0.52	0.67
BUS	0.91	0.91	0.88

Source: Minnesota HCAS 2012, Table 4.15, p. 56.

Exhibit 2 shows the adjusted ratios at the state level for the weight fees and the weight-mile fees under both scenarios. As the table illustrates, adjusted equity ratios under both weight-mile fee scenarios are closer to the target ratio (one) than the weight fees for most vehicle classes.

Auction-Based Permit System (ABPS)

This section discusses the development and testing of an ABPS that a state transportation agency could implement to learn the demand for permits and freight companies' willingness-to-pay for the permits. The researchers considered multi-item auctions and picked three mechanisms: Vickrey auction with reserve price, Ascending clock auction, and Clinched ascending clock auction. These three

mechanisms were picked because they satisfied the following criteria:

- The price paid by a winning bid depends only on the opposing participants' bids.
- Bidders do not gain from over-bidding or under-bidding their true demand.
- The objective of the auction mechanism is to maximize revenue per permit sold.

The report explores the three auction mechanisms and how utility maximizing freight companies would bid under a competitive Nash equilibrium for each mechanism. The researchers then designed an experiment to test the different mechanisms using University of Minnesota graduate students and MnDOT staff members. The results of the experiment indicate that the ascending clock mechanism provided the maximum revenue per permit sold. Issues of auction fairness were not discussed in the report. The report considers the outcome of an auction as efficient when the individual item is sold to the bidder with the highest valuation for the item.

HCAS METHODS

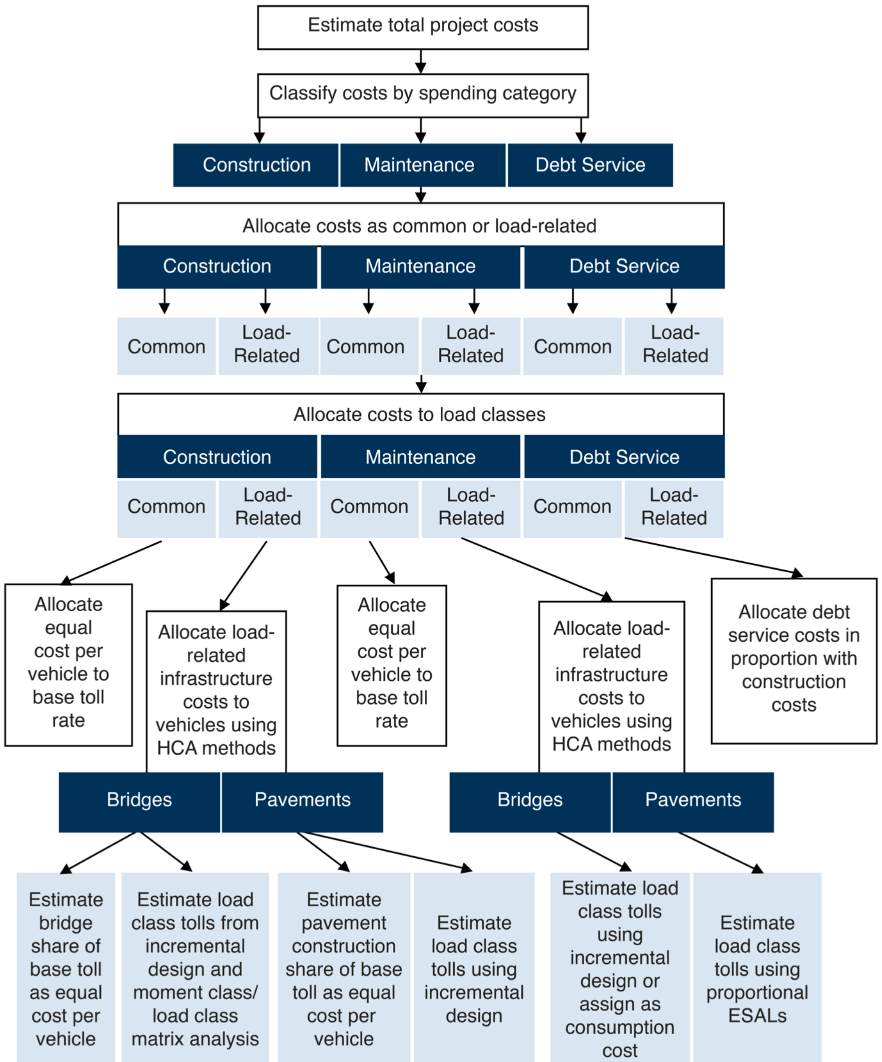
A Road Pricing Methodology For Infrastructure Cost Recovery, 2010 (By Conway & Walton)

The broad motivating question for the report is, "What future method of truck user charging can be employed to equitably recover infrastructure costs from individual vehicles based on real-time operations?" (Conway & Walton, 2010, p. 3). The report presents a framework for charging commercial vehicles using weigh-in-motion (WIM) systems. The WIM systems collect real-time vehicle weight and configuration information that can be used to charge vehicles on a toll structure. The report proposes using highway cost allocation methods to estimate a more equitable toll structure based on the individual axle weights that can be measured real-time using the WIM systems. The report presents a hypothetical case study using information from Texas State Highway 130 to consider the improvements in equity that could be realized using the proposed methodology. The study proposes a two-part toll. The first part is a base toll that is charged to all commercial and passenger vehicles that is calculated such that all common costs and basic infrastructure costs are recovered. The second part is an additional toll for heavy vehicles that is estimated using the "axle-load" estimation (preferred) or the "number-of-axle" estimation. Exhibit 3 (on the following page) illustrates the process.

Under an axle-load toll structure, heavy vehicles pay an additional cost per axle-load to recover infrastructure costs (pavement and bridge costs) that are required in order to support their weight. Pavement impacts are estimated as a function of individual axle loads, so initial load classes must be developed using the relative impacts on pavement by loads from individual classes. The particular characteristics of the facility with respect to traffic volumes, truck profiles, and axle load distribution need to be identified to determine the relative impacts of each class. Traffic analysis provides vehicle volumes, and WIM data can provide axle load distributions and truck profile information. This information can be used to calculate the probability that a load belongs to a given class and estimate the toll rates for each individual load class.

The case study considers State Highway 130 in Texas. The results indicate that the "axle-load" tolling structure recovers costs more equitable for heavy vehicle consumption than a "number-of-axle (n-1)" structure. The addition of an axle can lessen the load at a given point, reducing the pavement and bridge impacts. The pavement impact is lower from a 20,000 lb. load split across two axles than the same load on one axle. The "axle-load" structure is more effective at mirroring the estimated cost responsibility of different vehicle classes.

EXHIBIT 3. CENTER FOR TRANSPORTATION RESEARCH/SOUTHWEST REGION UNIVERSITY TRANSPORTATION CENTER - COST ALLOCATION METHOD FOR TOLL RATE DETERMINATION



Models For Highway Cost Allocation, 2013 (By Garcia-Diaz & Lee)

The report reviews the traditional HCAS methods, incremental or proportional (or a combination of the two) and then presents an alternative, non-traditional HCAS method that is based on concepts from the theory of cooperative games. The study considers how well different HCAS methods fulfill three fundamental properties: completeness, rationality, and marginality. Completeness means that highway costs are fully recovered by all participating vehicle classes. Rationality means that each vehicle class will have a lower cost by participating in the large group of all vehicle classes. Marginality means that each vehicle class pays the incremental cost that is incurred by including it in the grand coalition. Traditional HCAS methods, incremental and proportional, satisfy completeness. The incremental method sometimes satisfies marginality.

The non-traditional method presented in the paper, the Generalized Method (known as the Nucleolus Method in game theory) is based on concepts from the theory of cooperative games. Villarreal and Garcia-Diaz (1985) first proposed the use of this method in HCAS.[1] With this method, all three properties are forcibly satisfied as a result of constraints in the method's mathematical formulation. The generalized method guarantees "that every vehicle class will be allocated a lower cost in the grand coalition (all vehicle classes), as compared to any other smaller coalition (one with fewer vehicle classes than the grand coalition)" (Garcia-Diaz & Lee, 2013, p.137).

The average marginal cost for a vehicle class, considering all the permutations of vehicles in the grand coalition, is the Shapley Value. The Shapley Value represents the average marginal cost contribution that each vehicle class would make to the grand coalition if it were forming one vehicle class at a time (Garcia-Diaz & Lee, 2013, p.138). The Aumann-Shapley Value considers two types of costs, the sum of which is the total cost allocated to a vehicle class. The first cost is for ESALs (pavement thickness) and the second is for highway lanes (traffic capacity). The method calculates a cost per ESAL and a cost per lane. This procedure has a number of advantages and tackles some obstacles often found in traditional HCAS. It "allows the consideration of the number of lanes as being a variable and depending on the composition of the traffic using a

[1] A Development and Application of New Highway Cost Allocation Procedures. Villarreal-Cavazos A, Garcia-Diaz Transportation Research Record 1009: 34-41. 1985.

highway (Garcia-Diaz & Lee, 2013, p.138). This "addresses how seemingly conflicting objectives: lighter vehicles require less pavement thickness and more lanes while heavy vehicles require fewer lanes but thicker pavements" (Garcia-Diaz & Lee, 2013, p. 138). After calculating a cost per ESAL and a cost per lane, the method uses the Shapley Value to allocate the number of available lanes between vehicle classes. The paper provides examples using three vehicle classes.

The paper states that the Generalized Method distributes traffic-related costs more equitably than any other HCAS method, as it considers traffic loads and traffic capacity. The combination of the Aumann-Shapley Value (average cost per ESAL and average cost per lane) and the Shapley Value (used to allocate the total number of lanes among vehicle classes), allows for the possibility to calculate the cost per mile for each vehicle class. The paper also proposes a method for separating bridge construction and traffic capacity costs that is similar to the method for separating pavement thickness and traffic capacity costs. There is the additional step that allocates the traffic-load cost to each weight group in a vehicle class using the incremental method. The paper provides examples using three vehicle classes and four weight intervals.

Bridge Structure Comparative Analysis, Comprehensive Truck Size and Weight Limits Study, 2013

This study provides a list of agencies that provide technical support through research, ongoing studies, and practice. This list includes national programs such as the Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP) and Strategic Highway Research Program, (SHRP 2). It also includes federal and state transportation agencies and universities.

The second section of the study provides a list of documents that the study reviewed with a link to the document, a summary of the findings, and a discussion of the document's relevance to one of the Comprehensive Truck Size and Weight (CTSW) Study topics. A key discussion area is how to recover the relatively high structural and infrastructure costs on bridges from heavy trucks. The study examines resources in the literature from 1997 to 2013 that may inform approaches that may help recover these costs more equitably.

State Highway Cost Allocation Studies: A Synthesis Of Highway Practice, 2008 (By Balducci & Stowers)

This report is intended to help states with HCAS methods by laying the foundation on current HCAS methods and areas of improvement for HCAS methods. The report reviews the HCAS methods used by different states, the conceptual foundation of HCAS methods, methods for revenue attribution, and arising issues with HCAS methods.

Since the 1997 Federal HCAS, there have not been many major changes in HCAS practice. A significant development in the past few years was FHWA's completion of the development and refinement of the National Pavement Cost Model (NAPCOM) and its development of NAPCOM into a model that can be used in state level HCAS. The FHWA also developed generalized state level HCAS software and documentation for the software.

Exhibit 4 summarizes recent state HCASs. Much of the data in the table is from a previous study by ECONorthwest in 2005, but has been updated through 2023 by the research team. The results in the method column indicate that the Incremental and Federal Methods are most commonly used for state HCASs. These fall under the cost-occasioned approach that determines cost responsibility using the costs imposed on the highway by the highway-user class and not just by relative use. A key issue in HCAS is the cost responsibility of heavy-truck vehicle classes. Studies consistently find that heavy trucks payments do not fully cover their cost responsibility.

EXHIBIT 4. STATE HIGHWAY COST ALLOCATION STUDIES

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Arizona	1993, 1999, 2000, 2001, 2002, 2005	Federal	31.4% (1999)	VMT, Axle-Load, Gross Weight	State, Federal, and Local Funds Combined
Arkansas	1978	Incremental/Cost Function			
California	1987, 1997	Federal and Incremental	18.90%	ESALs	State, Federal, and Local Funds Analyzed Separately
Colorado	1981, 1988	Federal	37%	VMT, Truck-VMT, ESALs, Ton-Miles	
Delaware	1992, 1993	Federal and Incremental	20.33%	VMT, ESALs, PCE, Axle-Miles, Registrations	State and Federal Funds Combined Only
Florida	1979	Incremental	64.50%	VMT, ESALs, Axle-Miles, Registrations	State and Federal
Georgia	1979, 1982	Incremental	51.2% (1979)	VMT, ESALs, GVW, AMT	State and Federal
Idaho	1987, 1994, 2002, 2010	Prospective Cost- Occasioned, Modified Federal, NAPCOM	Federal & State: 43.5% or 40.9%* State: 40.6% or 34.1%*	VMT, ESALs, ADT	State, Federal, and Local Funds Combined
Indiana	1984, 1988, 1989,2000	Incremental/Consumption	53.20%	ESALs	State, Federal, and Local
Iowa	1983, 1984	Federal	48.94%	VMT, ESALs, Ton-Miles, AMT, PCE	
Kansas	1978, 1985	Hybrid	41.85%	VMT, ESALs, PCE, AMT, Ton-Miles, Number of Vehicles	State Funds
Kentucky	1992, 1994, 1996,1998, 2000	Federal	54.92%	VMT, ESAL-VMT, PCE, Axle-Miles	State and Federal Funds Combined
Maine	1956, 1961, 1982,1989	Hybrid/Expenditure Allocation	35.60%	VMT, ESALs, PCE, Delphi, TMT,Standard Vehicle Equivalent	State and Federal funds
Maryland	1989, 2009	Federal	33.30%		State and Local Funds
Minnesota	1990 2009, 2012	Federal and Incremental, Modified Federal	Federal & State: 29.47%	VMT, ESALs, ADT	State and Federal Funds Combined and State
Mississippi	1980	Incremental	36%	VMT, Truck-VMT	

EXHIBIT 4 (CONTINUED). STATE HIGHWAY COST ALLOCATION STUDIES

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Missouri	1984, 1987, 1990, 2018	Federal, Incremental		VMT, Vehicle Size, Vehicle Weight	
Montana	1992, 1999	Federal	33%	VMT, ESALs, AMT	
Nevada	1984, 1985, 1988, 1990, 1992, 1994, 1999, 2009	Modified Incremental, Modified Federal with NAPCOM (2009)	All Levels: 34.66% State: 38.26%	VMT, ESALs, Axle-Miles, Ton- Miles	State, Federal, and Local Separately and Combined
New Mexico	1972				
North Carolina	1983	Federal		VMT, ESALs, PCE, Weight Axle- Miles	State and Federal Funds
Oregon	1937, 1947, 1963, 1974, 1980, 1984, 1986, 1990, 1992, 1994, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021	Cost-Occasioned with NAPCOM for Pavement Costs (Since 1999)	31.20%	VMT, Congested PCE, Uphill PCE, Truck-VMT, Basic Vehicle VMT	State, Federal, and Local Combined for Cost Allocation Purposes but State Only for Revenue Attribution Purposes
Pennsylvania	1989, 1990	Federal/Cost-Occasioned			
Texas	1984, 1985, 1994, 2002				
Vermont	1990, 1993, 2006	Federal	25.70%	VMT, ESALs, ADT	State and Federal Funds
Virginia	1991, 1992	Federal	21.70%	VMT, ESALs, ADT	State and Federal Funds Combined
Washington	1977	Incremental			
Wisconsin	1982, 1992	Federal (1982)	31.70%	VMT, ESALs, PCE, Ton-Miles	State and Federal Funds Combined
Wyoming	1981, 1999	FHWA State HCAS Model	55.80%	VMT, Vehicle Size, Horsepower, Weight	

Source: Balducci and Stowers 2008. Adapted from ECONorthwest et al. (2005). Updated by ECONorthwest through 2023.

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ADDITIONAL HCAS STUDIES

Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees (MN/DOT): Task 1 Report – 2009 Minnesota Highway Cost Allocation Study.

Prior to the 2009 HCAS, Minnesota had conducted only one HCAS, roughly twenty years ago (published in 1989). Minnesota's 2009 HCAS was conducted by a faculty member and research assistant in the Engineering Department at the University of Minnesota. The study was conducted using FHWA's State HCAS program (HCASP), relying on some national default data and state-specific data when available. MNDOT provided financial (revenue and expenditure) and traffic data for the four-year period of July 2003 to 2007. Thus, the study is retrospective, in that it uses prior year expenditures and VMT; the study does not forecast future year spending, future expenditure work types, or VMT.

Following the Federal HCASP methodology, the study relied on the mapping of twelve HPMS vehicle classes into the 20 HCASP vehicle classes. The study used data from eleven weigh stations to develop distributions of registered Gross Weight for the vehicle classes. Default weight distributions from HCASP were used for those vehicle classes where the raw weigh station data could not be mapped into the HCASP vehicle classes.

The study found that the share of revenues from heavy vehicles is less than their share of costs.

Three "what-if" scenarios were analyzed to determine equity ratios under three different tax policies:

1. Increase in fees paid by vehicles greater than 16,000 lbs. by 26%.
2. Increase in the diesel tax by 25%.
3. Introduction of a weight-distance tax for vehicles more than 57,000 lbs.

Revenue Attribution

All federal, state, and local highway user revenues were included in the Minnesota HCAS. Federal revenues are based on those reported in the FHWA's Highway Statistics. The Federal HCASP contains default federal tax rates and attributes federal revenues to vehicle classes based on those rates and the VMT inputs. State highway user fees include motor fuel taxes, registration and license fees, vehicle sales tax, and an ad valorem tax. Similar to Nevada, Minnesota seems to include revenues that are diverted to non-highway uses. In the Minnesota HCAS, attributed state revenues exceed allocated state expenditures by 27%.

Cost Responsibility

Following the Federal State HCAS Program, the Minnesota HCAS categorized highway- related expenditures into 18 work categories. The work categories are typical highway project categories such as pavement (new, repair, etc.), bridge (new, replacement, rehabilitation), maintenance and administrative categories. Expenditures are also categorized by functional class, though administrative expenditures, rest area maintenance, state police and fuel/ registration collection costs are not assigned a road functional class.

Equity Ratios and Findings

Like the Nevada HCAS, the Minnesota HCAS reports unadjusted and adjusted equity ratios. The unadjusted equity ratio is computed as gross revenues divided by expenditures for each vehicle class and the adjusted equity ratios are the ratio of a vehicle class' revenue share to their share of expenditures. Revenue per mile and cost per mile for each vehicle class is reported along with equity ratios, with equity ratios for state and federal reported separately.

The study finds that vehicle classes with weights greater than 16,000 lbs. have adjusted ratios less than 1.0 for state ratio and vehicles under 26,000 lbs. have federal plus state adjusted equity ratios greater than 1.0.

The scenario analysis demonstrates that a 25% increase in the diesel fuel tax is more effective at bringing the heavy vehicle equity ratios closer to 1.0 than a 25% increase in heavy vehicle fees. Both of these two policy scenarios are more effective at bring equity ratios closer to 1.0 for vehicles between 16,000 and 50,000 lbs., but adjusted equity ratios remain rather low for vehicles weighing more than 50,000 lbs.

The third "what-if" scenario examined equity ratios using weight-mile tax applied to vehicles weighing 57,000 lbs. and greater. The weight-mile tax rates were estimated by fitting a segmented regression model to the difference between the allocated cost per mile and current revenue per mile using registered gross vehicle weight categories. Equity ratios for heavy vehicle classes are closer to 1.0–in particular the equity ratio for five-axle tractor trailers is 1.03 under the weight-mile tax. However many vehicle classes still have equity ratios under 1.0.

APPENDIX C: 2021–2023 SRT MEETINGS

For meeting recordings, please reference the Office of Economic Analysis Department of Administrative Services website on HCAS available here:
https://www.oregon.gov/das/oea/pages/hcas.aspx

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TABLE OF CONTENTS

MODEL OVERVIEW

The full source code for the 2023 Oregon Highway Cost Allocation Model is included with the model distribution. The model is written in Python and is implemented by running HCASModule.py. The process for running the model is described in depth in the Model User Guide.

The HCAS Python code is centered on a class, HCASModule, that calls a series of methods when the Python file is executed.

This appendix provides a detailed description of each of the class methods that are called in the HCAS Python model, explaining the calculations and describing the internal data structures they use. Figure 1 shows a graphical representation of the overall model process, including the Excel workbooks, the HCAS model, and the external data files. Figure 1 shows the required inputs, templates and outputs of the model. Each box shows the general filepath from the base folder where the file(s) is located. The Model User Guide provides a detailed overview of how these files are setup and where they are located in the HCAS model folder.

Table 1 describes the input ranges in various tabs of the "HCAS Inputs.xlsx" workbook, listing the input range name, the tab it is located in, the data it contains, the units those data are in, the class method that loads the data into the HCAS model code, and the name of the data structure in the HCAS model code that accepts the data.

Table 2 describes the tab-delimited text files that contain input data for the HCAS model, listing the file name, what data it contains, the units those data are in, and the data structure in the HCAS model that accepts the data.

Table 3 describes the outputs from the model code that populate the tabs in the "HCAS Outputs 2023.xlsx" workbook, listing the data structure in the HCAS model from which the data are extracted, the method called to calculate and retrieve the data, the tab into which the data are written, and the contents of the data.

Table 4 describes the tab-delimited text files that are written when the HCAS model runs, listing the data structure in the HCAS model from which the data are extracted, the method called to calculate and write the data, the file names, and the contents of the data.

FIGURE 1. OREGON HIGHWAY COST ALLOCATION MODEL

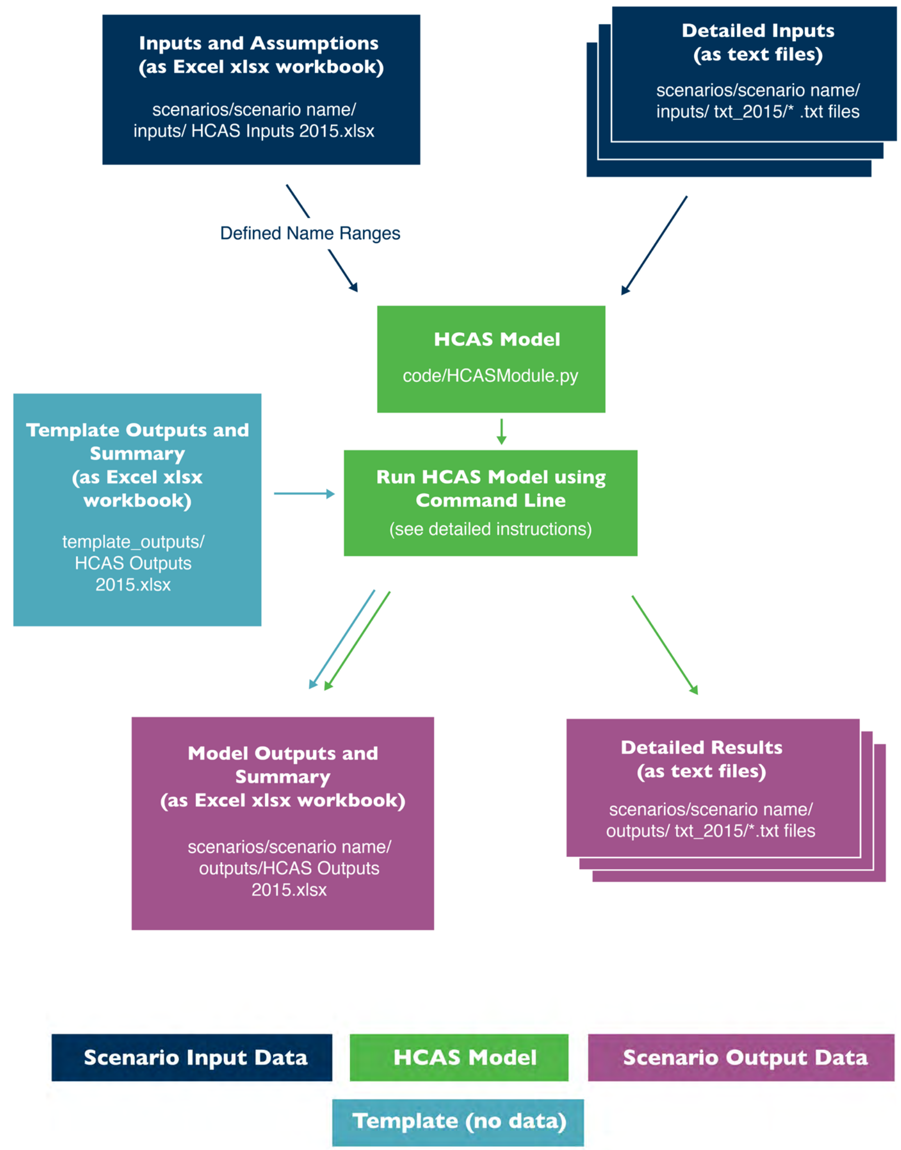

TABLE 1. INPUT RANGES

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
GrowthRates	VMT Growth	simpleSetup(xls_ inputs['GrowthRates'])	self.growthRates	Annual growth rate (e.g., 0.05 means 5% per year)	VMT growth rates
VMTByFC	VMT by FC	simpleSetup(xls_ inputs['VMTByFC'])	self.VMTbyFC	Base-year vehicle- miles traveled	VMT by functional class and ownership
BaseVMT	Base VMT	setBaseVMT(xls_ inputs['BaseVMT'])	self.baseVMT	Base-year vehicle- miles traveled	Base-year VMT by weight class and tax class
Evasion	General	setEvasion(xls_inputs['Evasion'])	self.gasEvasion, self. dieselEvasion, self. wmtEvasion, self. basicDiesel, self. ruafRegRate, self. ruafReg78, self.ruafReg96, self.ruafReg104, self. emptyLogPercent, self. emptyLogWeight	All are shares (e.g., 0.05 means 5%) except RUAF Registration Rate is in dollars per mile traveled and Empty Log Weight is in pounds	Assumptions for gas-tax avoidance, use-fuel tax evasion & avoidance, weight-mile tax evasion, share of basic VMT that burn diesel, registration rate per mile for RUAF vehicles, share of RUAF vehicles registered at 78,001- 80,000 lbs, share of RUAF vehicles registered at 96,001-98,000 lbs,share of RUAF vehicles registered at 104,001-105,500 lbs, percent of flat-fee log truck miles that are empty, declared weight for empty log trucks
Path	Policy	setPath(xls_inputs['Path'])	self.path	Names of allocators and shares	Allocator(s) to use for each work type
ProjectCosts	Project Costs	setProjectOrLocalCosts(xls_ inputs['ProjectCosts'])	self.projectCosts	Biennial dollars	Costs to allocate for construction projects
NonProjectCosts	Non-Project Costs	setNonProjectOrStuddedTire (xls_inputs['NonProjectCosts'])	self.nonProjectCosts	Biennial dollars	Other costs to allocate
LocalCosts	Local Costs	setProjectOrLocalCosts(xls_ inputs['LocalCosts'])	self.localCosts	Biennial dollars	Local-government costs to allocate
StuddedTire	General	setNonProjectOrStuddedTire (xls_inputs['StuddedTire'])	self.studdedTire	Biennial dollars	Studded-tire adjustments
BridgeFactors	General	setBridgeFactors(xls_ inputs['BridgeFactors'])	self.bridgeFactors	Shares	Incremental factors for bridge work types
BondFactor	General	float(xls_inputs['BondFactor'][0] [0])	self.bondFactor	Share	Proportion of bonded expenditures to allocate in a biennium
Biennium	General	int(xls_inputs['Biennium'][0][0])	self.biennium	Four-digit year	First year of model biennium
SWT	Codes	setSummaryTypesClasses(xls_ inputs['SWT'])	self.summaryWorkTypes	Work type codes	Definitions of summary work types
SWC	Codes	setSummaryTypesClasses(xls_ inputs['SWC'])	self. summaryWeightClasses	Pounds	Definitions of summary weight classes

TABLE 1 (CONTINUED). INPUT RANGES

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
RevenueTotals	Revenue Forecast	setRevenueTotals(xls_inputs['RevenueTotals'])	self.revenueTotals	Biennial dollars	Control totals for revenues by instrument
Rates	Rates	setRates(xls_inputs['Rates'])	self.rates	Dollars per whatever	Current-law rates except RUAF and flat fee
RUAFRates	Rates	setRUAFRates(xls_inputs['RUAFRates'])	self.RUAFRates	Dollars per mile	Current-law RUAF rates
FFRates	Rates	setFFRates(xls_inputs['FFRates'])	self.flatfee	Dollars per month, miles per month, and shares	Current-law flat fee rates
MPG	MPG		self.MPG	Miles per gallon	Assumed miles per gallon
AltRates	Alt Rates	setRates(xls_inputs['AltRates'])	self.altRates	Dollars per whatever	Alternative rates except RUAF and flat fee
AltRUAFRates	Alt Rates	setRUAFRates(xls_inputs['AltRUAFRates'])	self.altRUAFRates	Dollars per mile	Alternative RUAF rates
AltFFRates	Alt Rates	setFFRates(xls_inputs['AltFFRates'])	self.altFlatfee	Dollars per month, miles per month, and shares	Alternative flat fee rates

See: HCAS Inputs 2023.xlsx

TABLE 2. INPUT TEXT FILES

File Name	Model Data Structure	Units	Contains
SeedData.txt	self.seedData	Unitless numbers	Used to populate a preliminary VMT Master table (VMTdata) for iterative proportional fitting (see below). Any seed values (except zeros) could be used to generate fitted results, but this particular set already contains data that reflect the relative proportions of different vehicle types on different functional classes, and so will produce a distribution that not only adds up to the correct totals for each weight class and each combination of functional class and ownership, but also reflects the fact that some functional classes carry higher proportions of heavy vehicles than others. There are five columns: facility class (combines functional class and ownership), functional class, ownership, weight class, axles, and VMT. The first four are keys.
AxleShares.txt	self.shares	Shares (e.g. 0.5 means 50%)	Contains the shares of vehicles weighing more than 105,500 pounds with each number of axles (5 to 9+) by weight class. These data are developed from Special Weighings data. There are three columns: weight class, axles, and share. The first two are keys
SimpleFactors.txt	self.simpleFactors	Shares	Contains vectors of factors to be multiplied by VMT for simple allocators (different weight groupings of VMT). These factors are mostly zeros and ones, reflecting the definition of the allocator. For example, the Under26 factor is one for all weight classes up to 26,000 pounds and zero for all weight classes over 26,000 pounds. There are ten columns: weight class, axles, AllVMT, BasicVMT, Over10VMT, Over26VMT, Over50VMT, Under26VMT, Over80VMT, Over106VMT, Snow, and AllAMT. The first two are keys; the rest are allocators.
PaveFactors.txt	self.paveFactors	Shares	Contains cost responsibility factors (by weight class, functional class, and number of axles) for wear and tear of flexible and rigid pavement projects. These factors are produced by the NAPHCAS-OR model (the Oregon version of the National Pavement Cost Model for Highway Cost Allocation developed by Roger Mingo). There are five columns: facility class (combines functional class and ownership), weight class, axles, flexible, and rigid. The first three are keys.
PCEFactors.txt	self.pceFactors	Shares	Contains passenger car equivalents (PCEs) by weight class, functional class, and number of axles for vehicles on regular, uphill, and congested roadways. These factors represent the amount of roadway capacity a single vehicle of a particular weight class takes up as a proportion of the capacity consumed by a basic vehicle. These factors were developed from a study conducted as a part of the 1997 federal highway cost allocation study. There are six columns: facility class (combines functional class and ownership), weight class, axles, regularPCE, UphillPCE, and congestedPCE. The first three are keys.
DeclaredRegistered.txt	self.declaredRegistered	Shares	Contains shares of vehicles in each declared weight class that are registered in each registered weight class. These data were developed from Motor Carrier registration data. There are three columns: declaredWeight, registeredWeight, and share. The first two are keys.
DeclaredOperating.txt	self.declaredOperating	Shares	Contains shares of vehicles in each declared weight class operating at each operating weight class. These data were developed from the Special Weighings data. There are five columns: declared, declaredAxles, operating, operatingAxles, and Share. The first four are keys.
BasicSharePeak.txt	self.peakShares	Shares	Contains the basic-vehicle share of peak-hour VMT for each functional class. These data were developed from automatic traffic recorder data. There are two columns: functionalClass and share. The first is the key.
BondsYYYY-YYYY.txt	self.priorBondAmount	Biennial dollars	Contains allocated bonded expenditures from prior studies. Uses such files, if they exist, from the nine most recent prior biennia. Columns are declared weight class, declared number of axles, and dollars. The first two are keys. Actual files will have biennium beginning and ending years in place of “YYYY”.

TABLE 3. OUTPUTS

Tab	Model Data Structure	Method to Create	Units	Contains
Model VMT	self.vmtByVehicles	makeVMTByVehicles()	Annual vehicle-miles traveled	Model year VMT by weight class and tax class
Allocated Costs	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Allocated costs by declared weight class, declared number of axles, and funding source
Allocated Costs by SWT	self.fullAllocatedCosts	getAllocatedCosts ByWorkType()	Biennial dollars	Allocated costs by funding source, summary work type, and summary weight class
Costs to Allocate by SWT	self.projectCosts, self. nonProjectCosts, self.bondCosts, self. priorBondAmount	getCoststoAllocate()	Biennial dollars	Costs to allocate by funding source and summary work type
Attributed Revenues	attributedRevenues	attributeRevenues()	Biennial dollars	Attributed revenues by declared weight class, declared number of axles, and revenue instrument
Alt. Attributed Revenues	attributedRevenues	attributeAltRevenues()	Biennial dollars	Attributed alternative revenues by declared weight class, declared number of axles, and revenue instrument
MPG	self.adjustedMPG	getAdjustedMPG()	Miles per gallon	Calibrated estimates of miles per gallon by weight class

See: HCAS Inputs 2023.xlsx

TABLE 4. OUTPUT TEXT FILES

Tab	Model Data Structure	Method to Create	Units	Contains
AllocatedCosts_bond.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from current and prior bonded expenditures. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_federal.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of federal funds by state government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_local-federal.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of federal funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_local-other.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of local funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.

TABLE 4 (CONTINUED). OUTPUT TEXT FILES

Tab	Model Data Structure	Method to Create	Units	Contains
AllocatedCosts_local-state.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of state funds by local government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
AllocatedCosts_other.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Not used. This may be ignored.
AllocatedCosts_state.txt	self.fullAllocatedCosts	allocateCosts()	Biennial dollars	Contains allocated costs from the expenditure of state funds by state government. Columns are funding source, work type, declared weight class, declared number of axles, and dollars. The first four are keys.
BondsYYYY-YYYY.txt	allocatedBonds	allocateCosts()	Biennial dollars	Contains allocated bonded expenditures from this study. Will be used for the next nine biennia as an input file. Columns are declared weight class, declared number of axles, and dollars. The first two are keys. Actual file name will have beginning and ending years of the model biennium in place of "YYYY".
DeclaredPaveFactors.txt	self.pavement	makeVMTMaster()	Unitless factors	Contains pavement factors by facility class, declared weight class, and declared number of axles that are constructed from the raw pavement factors, which are by functional class, operating weight class, and actual number of axles. Columns are facility class, functional class, ownership, declared weight class, declared number of axles, flexible factor, and rigid factor. The first five are keys.
FlatFeeReport.txt	ffRevenue, asifWMTRevenue	allocateCosts()	Biennial dollars	Reports fees paid by flat-fee vehicles and the fees they would pay if they paid weight-mile tax. The 'as-if' revenue is to determine the flat fee difference. As of the 2011 study, flat-fee vehicles are not considered alternative fee-paying vehicles. Columns are declared weight class, declared number of axles, log revenue, as-if log revenue, dump revenue, as-if dump revenue, chip revenue, and as- if chip revenue. The first two are keys.
MissingPavementFactors.log	N/A	makeVMTMaster()	N/A	Lists any errors encountered while attempting to make pavement factors by facility class, declared weight class, and declared number of axles from raw pavement factors, which are by functional class, operating weight class, and actual number of axles.
VMTMaster.txt	self.VMTMaster	makeVMTMaster()	Annual vehicle-	Costs to allocate by funding source and summary work type
miles traveled	Contains annual VMT. Columns are functional class, ownership, declared weight class, declared number of axles, and vehicle-miles traveled. The first four are keys.	attributeRevenues()	Biennial dollars	Attributed revenues by declared weight class, declared number of axles, and revenue instrument
SubsidiesbyVehClass.txt	ffRevenue, regRevenue, ruafRevenue, wmtRevenue, gasTaxRevenue, dieselTaxRevenue, asifWMTRevenue	allocateCosts()	Biennial dollars	Contains calculated subsidies by subsidy type for WMT, Farm Registration, Tow Registration, Charitable Non-Profit Registration and E-Plate Registration for each weight class, and actual number of axles.

DESCRIPTION OF MODEL CALCULATION OPERATIONS

The following describes what happens when the Python HCAS model, HCASModule.py, is run. Figure 1 on page 24 illustrates the overarching process of the model. The model loads text files and tabs from the HCAS Inputs Excel workbook, performs calculations in Python, and then populates tabs with the results into the HCAS Outputs Excel workbook and saves output text files with detailed results.

Send Base-Year VMT Data & Retrieve Model-Year VMT Data

Growth rates, from the *VMT Growth* tab, tell the model how fast VMT in each weight class is expected to grow between the base year (the most recent calendar year for which data are available) and the model year (the calendar year in the middle of the fiscal biennium being modeled).

VMT by functional class, from the *VMT by FC* tab, provides control totals for base-year VMT in each functional class. Base VMT, from the *Base VMT* tab, provides base-year VMT by weight class and tax class.

Evasion rates, from the *General* tab, tell the model what evasion and avoidance rates to assume. Evasion and avoidance are combined.

The call to makeVMTMaster() tells the model to do its VMT calculations. The call to makeVMTByVehicles() tells the model to calculate model- year VMT by weight and tax class and populate the *Model VMT* tab in the outputs workbook.

Send Costs to Allocate & Retrieve Allocated Costs

The path, defined in the *Policy* tab, defines the set of allocators to be applied to each work type. Each work type may have up to two allocators. If there are two, the proportion of costs in that work type to which each will be applied is also defined in the path. The proportions must add up to one.

The model obtains costs to allocate from the *Project Costs, Non-Project Costs*, and *Local Costs* tabs. Items (rows) in the lists of costs to allocate include information about the funding source, work type, functional class, and dollar amount. Project costs also include the bridge type, which is zero if the project is not a bridge project.

The model obtains studded-tire adjustments from the Studded Tires table in the *General* tab. These move costs from their original combination of funding source and work type into the studded tire work type with the same funding source.

The model obtains bridge factors from the Bridge Splits table in the *General* tab. These factors are used to reassign bridge costs from their original work types to incremental cost work types so that incremental allocators may be applied. There will be a set of factors for each bridge type.

The model obtains the information necessary for the proper treatment of the expenditure of bond revenues from the *General* tab.

The *Codes* tab allows the model to tabulate allocated costs by summary work type and summary weight class for the report tables. These tabulations are done in the model, rather than in workbook, since it is faster, more reliable, and keeps the workbook size reasonable.

The allocateCosts() method allocates costs and returns the allocated costs by weight class and funding source, which then populate the *Allocated Costs* tab in the outputs workbook.

Send Revenues & Rates & Retrieve Attributed Revenues

The model obtains revenue totals that are the control totals by instrument from the budget. Revenues are located in the *Revenue Forecast* tab in the inputs workbook. Rates are located in the *Rates* tab in the inputs workbook. Rates are for instruments that vary by weight class (e.g., weight-mile tax rates) or not at all (e.g., fuel taxes). The two other types of rates have different dimensions, so are sent separately. RUAF rates extend to a much longer list of weight classes. Flat-fee rates are by commodity and include information about the average miles per month for each weight class and the distribution of VMT in each weight class to numbers of axles for weights over 80,000 pounds. The model obtains estimated miles per gallon by operating weight class from the *MPG* tab in the inputs workbook.

The attributeRevenues() method attributes revenues and returns the attributed revenues by weight class and revenue instrument, which then populate the *Attributed Revenues* tab in the outputs workbook.

The call to getAdjustedMPG() tells the model to return the adjusted miles per gallon (already calculated as part of the revenue attribution calculations), which then populate the *MPG* tab of the outputs workbook to the right of the initial MPG estimates. The initial estimates are adjusted to allow fuel tax revenues to add up the revenue control totals for fuel taxes.

Retrieve Summary Tabulations for Report Tables

The getAllocatedCostsByWorkType() method gets allocated costs by summary work type, funding source, and summary weight class, which then populate *Allocated Costs by SWT* tab in the outputs workbook.

The getCostsToAllocate() method returns costs to allocate by summary work type and funding source, which then populate the *Costs to Allocate by SWT* tab in the outputs workbook.

Send Alternative Rates & Retrieve Attributed Alternative Revenues

The model obtains alternative rates from the *Alt Rates* tab. These alternative rates are used for policy analysis to test the effect on equity of proposed changes to revenue instruments. They do not require changes to revenue control totals, because they use the calibrated miles per gallon and miles per registration from the original revenue attribution calculations, which were calculated from the control totals and rates provided there.

The attributeAltRevenues() method attributes revenues using alternative rate schedules and returns results by weight class and revenue instrument, which populate the *Alt. Attributed Revenues* tab in the outputs workbook.

DESCRIPTION OF MODEL CLASS METHODS

The following sections of the documentation serve two purposes: they describe in detail how the model does what it does and they provide a guide for following the source code. The class methods are described in the order they appear in the source code, which is the order in which they are called in running the model. The first section describes the class methods that load the input data into the model. The subsequent sections describe the way the model analyzes VMT, allocates costs, and attributes revenues.

METHODS TO LOAD DATA

The class methods described in this section serve to get data into the HCAS model. Data that are not expected to be changed by the user are read in from tab-delimited text files. Data and assumptions that an analyst is more likely to want to change between model runs are loaded from the HCAS Inputs Excel workbook. Other class methods, described in later sections, make use of the data and return results to the HCAS Outputs Excel workbook and additional, more-detailed data to tab-delimited text files.

Note that variables beginning with "self." belong to the class object and are available to any class method to which the self reference has been passed. Other variables are available only within the method that creates them.

Load Text Input Data

The readData() method imports the following data sets from tab-delimited text files, which are expected to be in the inputs text folder:

- AxleShares.txt is read into self.shares and contains the shares of vehicles weighing more than 105,500 pounds by number of axles (5 to 9+) by weight class. These data are developed from Special Weighings data to describe the share of each weight class with each possible number of axles (nine or more axles are coded as nine-plus). There are three columns: weight class, axles, and share. The first two are keys.
- BasicSharePeak.txt is read into self.peakShares and contains the basic-vehicle share of peak-hour VMT for each functional class. These data were developed from automatic traffic recorder data. There are two columns: functionalClass and share. The first is the key.
- DeclaredOperating.txt is read into self.declaredOperating and contains shares of vehicles in each declared weight class operating at each operating weight class. These data were developed from the Weigh-in-Motion data. There are five columns: declared, declaredAxles, operating, operatingAxles, and share. The first four are keys.
- DeclaredRegistered.txt is read into self.declaredRegistered and contains shares of vehicles in each declared weight class that are registered in each registered weight class. These data were developed from Motor Carrier and DMV registration data. There are three columns: declaredWeight, registeredWeight, and share. The first two are keys.

- PaveFactors.txt is read into self.paveFactors and contains cost responsibility factors (by weight class, functional class, and number of axles) for wear and tear of flexible and rigid pavement projects. These factors are produced by the NAPHCAS-OR model (the Oregon version of the National Pavement Cost Model for Highway Cost Allocation developed by Roger Mingo). There are five columns: facility class (combines functional class and ownership), weight class, axles, flexible, and rigid. The first three are keys.
- PCEFactors.txt is read into self.pceFactors and contains passenger car equivalents (PCEs) by weight class, functional class, and number of axles for vehicles on regular, uphill, and congested roadways. These factors represent the amount of roadway capacity a single vehicle of a particular weight class takes up as a proportion of the capacity consumed by a basic vehicle. These factors were developed from a study conducted as a part of the 1997 Federal Highway Cost Allocation Study. There are six columns: facility class (combines functional class and ownership), weight class, axles, regularPCE, uphillPCE, and congestedPCE. The first three are keys.
- SeedData.txt is read into self.seedData and used to populate a preliminary VMT Master table (VMTdata) for iterative proportional fitting (see below). Any seed values (except zeros) could be used to generate fitted results, but this particular set already contains data that reflect the relative proportions of different vehicle types on different functional classes, and so will produce a distribution that not only adds up to the correct totals for each weight class and each combination of functional class and ownership, but also reflects the fact that some functional classes carry higher proportions of heavy vehicles than others.There are five columns: facility class (combines functional class and ownership), functional class, ownership, weight class, axles, and VMT. The first four are keys.
- SimpleFactors.txt is read into self.simpleFactors and contains vectors of factors to be multiplied by VMT for simple allocators (different weight groupings of VMT). These factors are mostly zeros and ones, reflecting the definition of the allocator. For example, the Under26 factor is one for all weight classes up to 26,000 pounds and zero for all weight classes over 26,000 pounds. There are twelve columns: weight class, axles, AllVMT, BasicVMT, Over10VMT, Over26VMT, Over50VMT, Under26VMT, Over80VMT, Over106VMT, Snow, and AllAMT. The first two are keys; the rest are allocators.

Load Excel Input Data

Input data from the HCAS Inputs Excel workbook are loaded from the workbook using loadExcelInputData() method. This function takes the filename of the input workbook as an argument. In the 2023 HCAS, the model expects the HCAS Inputs Excel workbook to be in the inputs folder and have the filename 'HCAS Inputs 2023.xslx'. A more detailed explanation of the inputs workbook setup is provided in the Model User Guide.

Load Data for VMT Analysis

The following class methods process the loaded data for the VMT calculations. The HCAS model calls these methods to process data for the model before it calls the makeVMTMaster() method.

- simpleSetup sets up data (in this case, Growth Rates and VMTbyFC) that has a shared format.

  Captures VMT growth rates by weight class and puts them into self.growthRates. The key is weight class and values are annual growth rates for VMT.

  Captures base-year VMT by functional class and ownership and puts them into self.VMTbyFC. The key is facility class (combination of functional class and ownership) and the values are base-year VMT. These data are developed from the state's HPMS submission and FHWA Highway Statistics reports.
- setBaseVMT() 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() captures evasion and avoidance rates, along with some other assumptions used in revenue attribution. These assumptions are specified by the analyst. The function puts the assumptions into:
  - self.emptyLogWeight (the assumed declared weight of an empty log truck with its trailer decked).
  - self.emptyLogPercent (the assumed share of log-truck VMT that are driven while empty and with the trailer decked).
  - self.ruafReg104 (the assumed share of RUAF VMT by trucks with a registered weight of 104,001 to 105,500 pounds).
  - self.ruafReg96 (the assumed share of RUAF VMT by trucks with a registered weight of 96,001 to 98,000 pounds).
  - self.ruafReg78 (the assumed share of RUAF VMT by trucks with a registered weight of 78,001 to 80,000 pounds).
  - self.ruafRegRate (the assumed per-mile registration fee paid by trucks that pay the RUAF).
  - self.basicDiesel (the assumed proportion of basic VMT by diesel-powered cars and light trucks).
  - self.wmtEvasion (the assumed percent of total miles traveled by WMT vehicles upon which taxes are not paid).
  - self.dieselEvasion (the assumed percent of VMT by use-fuel-tax-paying vehicles for which the use-fuel tax was not paid; includes evasion and avoidance).
  - self.gasEvasion (the assumed percent of VMT by gas-tax-paying vehicles for which the gas tax was not paid; probably is entirely avoidance).

Load Data for Cost Allocation

The following class methods capture data from the inputs workbook for the cost allocation calculations and are called before the model calls the allocateCosts() method.

- setPath() captures allocation rules to be applied to each expenditure category (work type) and puts them into self.path. self.path is a nested dictionary. Outer keys are work-type codes and inner keys are allocator names. Values are shares of costs in that work type to which that allocator should be applied. These assumptions are specified by the analyst in conformance with the approach agreed upon by the Study Review Team.
- setProjectOrLocalCosts() sets up data (e.g., self.projectCosts and self. localCosts) that has a shared format.

  Captures project costs to be allocated and puts them into self. projectCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type. The values are biennial dollars of costs to allocate. These are typically derived from the ODOT Cash Flow Model and Project Control System.

  Captures local government costs to be allocated and puts them into self. localCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type. The values are biennial dollars of costs to allocate. These are typically derived primarily from Local Roads and Streets Survey reports.
- setNonProjectOrStuddedTire() sets up data (e.g., self. nonProjectCosts and self.studdedTire) that has a shared format.

  Captures non-project costs to be allocated and puts them into self. nonProjectCosts. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type (always zero). The values are biennial dollars of costs to allocate. These are typically derived from the Agency Request Budget.

  Captures studded tire costs to be allocated and puts them into self. studdedTire. The key is a tuple consisting of funding source, work type, facility class (combination of functional class and ownership), and bridge type (always zero). The values are biennial dollars of costs to allocate, which will later be moved from the work types specified here into the work type for studded tire damage. These assumptions are supplied by the analyst.
- setBridgeFactors() captures cost shares used to distribute bridge expenditures for incremental cost allocation and puts them into self. bridgeFactors, a nested dictionary. The outer key is the bridge type and the inner key is a bridge-reclassification work type. Values are shares of costs for that bridge type to be allocated according to that work type. Shares for each bridge type must add up to one. The default values for these assumptions were developed from the 2002 OBEC Bridge Cost Allocation Study.

- self.bondFactor is defined as the proportion of bond-funded expenditures that will be repaid in a single biennium. This assumption is specified by the analyst. It represents the biennial repayment amount as a proportion of the principal amount.
- self.biennium is defined as the starting year of the model biennium. Specified by the analyst.

Load Data for Revenue Attribution

The following class methods capture data from the inputs workbook for the revenue attribution calculations. The HCASModule calls these methods to give data to the model before calling the standard implementation attributeRevenues() method or the alternative implementation attributeAltRevenues() method. The alternative rates are specified by the analyst to test changes in policy.

- setRevenueTotals() captures revenue control totals and puts them into self.revenueTotals. The key is the name of the revenue instrument and the value is biennial dollars of revenue to attribute. These are typically derived from the Agency Request Budget and must be consistent with current-law rates and the VMT data and assumptions specified elsewhere.
- simpleSetup sets up data (in this case, MPG) that has a shared format. Captures initial MPG assumptions by weight class and puts them into self.MPG. The key is operating weight class and values are miles per gallon. The default values for these assumptions were derived from a regression analysis of Vehicle Inventory and Use Statistics (VIUS) data.
- setRates() captures current-law (or alternative) rates for each of gas tax, use-fuel tax, VMT tax, weight mile tax, normal registration, farm registration, tow registration, charitable/nonprofit registration, e-plate registration, light-trailer registration, heavy-trailer registration, and title fees and puts them into self.rates (or self.altRates). self.rates (or self.altRates) is a nested dictionary. The outer keys are revenue instruments and the inner keys are tuples of weight class and number of axles. Values are rates in dollars per VMT, gallon, or year, as appropriate. For the standard implementation, these are specified by the analyst based on current law and must match the assumptions used to develop the revenue control totals. For the alternative implementation, these are specified by the analyst to test proposed changes to rates.
- setRUAFRates() captures current-law (or alternative) road-use assessment fee rates and puts them into self.RUAFRates (or self.altRUAFRates). The key is a tuple consisting of weight class and number of axles and values are dollars per mile. For the standard implementation, these are specified by the analyst based on current law. For the alternative implementation, these are specified by the analyst to test proposed changes to rates.
- setFFRates() captures current-law (or alternative) monthly flat-fee rates, average monthly miles, and axle distribution and puts them into self.flatfee (or altFlatfee). The key is one of 'Log Rate', 'Dump Rate', 'Chip Rate', 'Log VMT', 'Dump VMT', 'Chip VMT', 'Log Axles', 'Dump Axles', or 'Chip Axles' and the values are rates in dollars per month, average miles per month, or shares of VMT in that weight class accounted for by trucks with that number of axles, as appropriate. For the standard implementation, rates are specified by the analyst based on current law and the assumptions about average miles per month and distribution of miles among numbers of axles are derived from flat- fee reports from MCTD. For the alternative implementation, rates are specified by the analyst to test proposed changes to rates.

Load Data for Summary Tables

The following class methods capture data from the inputs workbook and use it to tabulate summary tables of allocated costs and costs to allocate. The HCASModule calls these methods to give data to the model before calling the getAllocatedCostsByWorkType() and getCostsToAllocate() methods.

- setSummaryTypesClasses()

  Captures definitions of summary work types and puts them into self.summaryWorkTypes. The key is the work type and the value is the summary work type.

  Captures definitions of summary weight classes and puts them into self.summaryWeightClasses. The key is the weight class and the value is the summary weight class.

VMT ANALYSIS METHODS

The makeVMTMaster() method 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() sums VMTData by functional class and ownership across weight classes and numbers of axles.
- findVCSums() sums VMTData by weight class and number of axles across functional class and ownership.
- scaleToFC() multiplies each value in VMTData by the ratio of its FCTotal control total to its current FCSum.
- scaleToVC() multiplies each value in the VMTData by the ratio of its VCTotal control total to its current VCSum.
- findSSE() calculates the sum of squared errors for the FCSums. (The SSE for VCSums will equal zero because the scaling process for VCSums runs after scaling for FCSums.) The “errors” are differences between the sums of VMT by individual facility class and the control total for that facility class. They are squared (multiplied by themselves) before adding up over facility classes for two reasons: positive and negative differences can’t cancel each other out and a large difference in an individual facility class will be given greater weight than several small differences that add up to the large difference. It is important that none be off by a lot, but it is acceptable for many to be off by a tiny amount each.

How makeVMTMaster() Works

VMTMaster is a matrix of vehicle-miles traveled (VMT) by vehicle classes and by road classes. Vehicle classes are combinations of 2,000-pound weight increments and numbers of axles. Road classes are combinations of functional classes (defined by the Federal Highway Administration) and ownership.

We start with base-year VMT by declared weight class by tax class to develop the row totals. Vehicles weighing 80,000 pounds and under are not classified by axles (axles=0). Base-year VMT by weight-mile-tax vehicles between 80,000 and 105,500 pounds are available by numbers of axles because the tax rate varies with the number of axles. Other vehicles in this range (e.g., farm, publicly-owned, or road-use assessment fee) are assumed to have the same distribution of miles by number of axles within each weight class as weight-mile tax vehicles.

Base-year VMT by road-use-assessment-fee vehicles weighing more than 105,500 pounds are distributed among numbers of axles according to the proportions specified in self.axleShares. A dictionary named VCTotals, keyed by weight class and number of axles, is built to contain the row totals for the VMT Master matrix.

The column totals are copied from self.VMTbyFC and scaled to add up to exactly the same total as the row totals. The individual cells of the VMT Master matrix are initialized with the proportions from self.seedData. The columns initially sum to one.

The iterative proportional fitting follows the following steps:

1. Scale each column so that it adds up to its column control total (scaleToFC())
2. Sum each row (findVCSums())
3. Scale each row so that it adds up to its row control total (scaleToVC())
4. Sum each column (findFCSums())
5. Find the sum of squared differences between column totals and column control totals and compare to the threshold value (findSSE()). The threshold value is arbitrarily set to 48, meaning that if each of the 48 facility classes was off by less than one vehicle mile traveled (out of a total of more than 30 billion), it would be satisfied.
6. If the sum of squared errors is less than the threshold, stop. Otherwise, return to Step 1.

Once iterative proportional fitting is complete, the growth rates for each weight class from self.growthRates are applied to the fitted base-year VMT data to bring it to the model year (the middle 12 months of the study biennium).

Three additional, summary facility classes are then added to the matrix. FC 0 is all state-owned roads, FC -1 is all roads, and FC -2 is all locally owned roads.

VMTMaster is copied to self.VMTMaster for use by other methods, is written to disk, and selected portions (FC -2 to FC 0, and all combinations of state ownership and functional class) are returned to the Model VMT tab in the outputs workbook.

The key in self.VMTMaster is a tuple consisting of facility class, declared weight class, and declared number of axles. Values are model-year VMT.

Once VMTMaster is built, it is used to convert self.paveFactors, which are by operating weight, actual number of axles, and functional class, into factors by declared weight class, declared number of axles (zero if declared weight under 80,000 pounds and nine if nine or more), and facility class (combinations of functional class and ownership, including the aggregate facility classes for all roads, all state-owned roads, and all locally owned roads), which are stored in self.pavement and used in allocateCosts() to allocate pavement costs to declared weight classes. The factors in self. pavement are VMT-weighted averages of the factors in self. paveFactors. Factors are constructed for both flexible and rigid pavements.

The structure of self.pavement is a nested dictionary. The outer key is the pavement type (Flex or Rigid) and the inner key is a tuple consisting of facility class, declared weight class, and declared number of axles. The code for preparing the pavement factors is intermingled with the code for building VMTMaster to save repeated looping over the same data structures.

The makeVMTByVehicles() method multiplies VMT values in self. baseVMT by the appropriate compounded growth rates to produce self. vmtByVehicles, which contains model-year VMT by weight class and tax class. These are returned to the HCAS Outputs workbook. self. vmtByVehicles is a nested dictionary. The outer key is the tax class and the inner key is the weight class.

COST ALLOCATION METHODS

The **allocateCosts()** method performs the following processes:

- Combine local costs data from self.localCosts with project costs data from self.projectCosts into self.projectCosts.
- Do bridge splits on project costs. 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. 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. 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. 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 thatcombination 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. 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.
- Make Other Bridge and Other Construction allocators. 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.
- Apply allocators to non-project costs. 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. Applies the allocators to bondstoAllocate and stores the result in allocatedBonds.
- Store allocated bonded costs. 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. Captures allocated, current payments due on bonds issued for projects in previous biennia (priorBonds).
- Add current and prior allocated bonded costs to allocatedCosts.
- Write out detailed allocation results to tab-delimited text files, one for each funding source. These are named AllocatedCosts_federal.txt, AllocatedCosts_state.txt, etc.
- Copy allocators to self.allocators and allocatedCosts to self.fullAllocatedCosts.
- Prepare a summary table of allocated costs and that is returned to the HCAS Outputs workbook. 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 gets the allocation vectors from self.allocators. Columns are allocators and rows are combinations of facility class, declared weight class, and declared number of axles.

The **getAllocatedCostsByWorkType()** method gets allocated costs from self.fullAllocatedCosts and aggregates them by summary work type from self.summaryWorkTypes and by summary weight class from self.summaryWeightClasses and returns the aggregated allocated costs to the Allocated Costs by SWT tab in the outputs workbook. Columns are summary weight classes and rows are combinations of funding source and summary work type. Cells contain allocated biennial dollars.

The **getCostsToAllocate()** method gets costs to allocate from self.projectCosts (which now includes local costs and excludes bonded costs), self.nonProjectCosts (which now excludes bonded costs), self.bondCosts, and self.priorBondAmount and aggregates them by summary work type from self.summaryWorkTypes. It returns the aggregated costs to allocate to Costs to Allocate tab in the outputs workbook. Note that prior bond amounts do not contain information about their original work type and are put into their own summary work type (21). Columns are funding sources and rows are summary work types. Cells contain biennial dollars.

REVENUE ATTRIBUTION METHODS

The **attributeRevenue()** method performs the following processes:

- Attribute road-use assessment fee (RUAF) revenue. 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. 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. For each flat-fee commodity (log, dump, and chip), for each combination of weight class and number of axles, divide the model-year VMT by the average VMT per month for that commodity and weight, and multiply the resulting number of vehicle-months by the appropriate monthly flat-fee rate. As-if weight-mile taxes for flat-fee-paying vehicles are calculated at the same time. For flat- fee log trucks, the model VMT must be adjusted prior to estimating as-if WMT revenues. When paying the WMT, log trucks can declare a lower weight when empty and traveling with their trailer decked. When estimating as-if WMT revenues for flat-fee log trucks, VMT in each weight class are multiplied by (1.0 - self.emptyLogPercent) and then by the WMT rate appropriate to that weight class. The VMT then are multiplied by self.emptyLogPercent and the WMT rate appropriate to self.emptyLogWeight. The flat-fee and as-if WMT revenues are doubled to make them biennial and stored in ffRevenue and asifWmtRevenue, respectively. A tab-delimited text file, FlatFeeReport.txt, containing flat-fee VMT, revenues, and as-if WMT revenues by commodity and weight class is written out to disk as a text file.
- Attribute registration and title revenues. 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 General tab of the HCAS Inputs workbook. It multiplies the fee per year by the VMT per year by the vehicles subject to that fee (as if the rate were per VMT). It then adds up those (large) numbers for each instrument and divides the biennial revenue control total for that instrument by the sum of annual miles times annual fee for that instrument. It applies that ratio to the annual miles times annual fee for each combination of declared weight class and declared number of axles to get biennial revenues for that combination and instrument.
- For vehicles over 26,000 pounds, an individual vehicle will have one registered weight, but may have multiple declared weights, depending on configuration. When getting the annual VMT to multiply by each rate, self.declaredRegistered, which contains the proportion of VMT for each declared weight class that is in each registered weight class, is used.
- For vehicles over 80,000 pounds, the revenues are attributed to 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. 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. Gasoline and diesel fuel tax revenues are attributed separately because the model allows for different tax rates and different evasion/avoidance assumptions. VMT by fuel type and weight class for fuel-tax paying vehicles are assembled and adjusted for evasion/avoidance. A preliminary attribution is made by dividing the adjusted VMT in each combination of weight class and fuel type by the assumed miles per gallon for that weight class from the MPG data set and multiplying the resulting number of gallons by the per-gallon rate for that fuel type. The attribution to vehicles between 10,001 and 26,000 pounds is then adjusted to bring those weight classes, as a group, to equity (before considering subsidies). The attribution to basic vehicles (those 10,000 pounds and under) is adjusted to make the total revenues attributed add up to the forecast revenues from the budget. The implied miles per gallon after adjustment for each weight class is calculated and returned to the MPG tab in the outputs workbook where it may be examined for reasonableness. The reasons for using this approach are detailed in Issue Paper 6 from the 2005 study.
- The first step in attributing fuel tax revenues is finding the taxed VMT by weight class for the gas tax and for the use-fuel (diesel, etc.) tax, taking into account avoidance, evasion, the portion of basic vehicles that do not burn gasoline, and the fact that publicly owned vehicles such as transit and school buses do not have to pay the use-fuel tax.
- The taxed VMT for each weight class is divided by the assumed miles per gallon from self.MPG and multiplied by the tax rate per gallon to get revenues by weight class. The assumed miles per gallon for vehicles between 10,001 and 26,000 pounds are then adjusted to force those weight classes into perfect equity (before the subsidy adjustment) and their attributed fuel-tax revenues are recalculated. The sum of attributed non-basic (over 10,001 pounds) fuel taxes are subtracted from their revenue control totals, leaving the amount from basic vehicles. The assumed average basic-vehicle is then recalculated so that basic vehicles will produce this amount of revenue and that amount is attributed to basic vehicles. The calibrated miles-per-gallon assumptions are stored in self.adjustedMPG.
- Attribute other motor carrier revenue. 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. These are calculated for each tax class by subtracting what they do pay in each revenue category from what they would pay if they paid the "regular" tax or fee. Subsidy amounts may be negative.
- Prepare a table of attributed revenues and subsidy amounts to save to a tab in the outputs workbook.

Attributed revenues are saved in the Attributed Revenues tab of the outputs workbook. getAdjustedMPG() returns the calibrated miles-per-gallon assumptions from self.adjustedMPG to the MPG tab in the outputs workbook.

ALTERNATIVE REVENUE ATTRIBUTION METHODS

The attributeAltRevenues() method repeats the revenue attribution process using alternative rates specified by the analyst in the *Alt. Rates* tab of the inputs workbook.

The process for alternative revenue attribution is essentially the same as for the primary revenue attribution, but there are important differences:

- When attributing registration and title fee revenues, assume that the revenues per VMT for each combination of instrument and weight class will change by the ratio of alternative rate to original rate. This allows estimating revenues from alternative registration and title fees without specifying the total revenue they will produce in advance.
- When attributing fuel-tax revenues, use the calibrated miles per gallon from the original revenue attribution. This allows estimating revenues from alternative fuel-tax rates without specifying the total revenue they will produce in advance.

Alternate attributed revenues are saved in the *Alt. Attributed Revenues* tab of the outputs workbook.

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MODEL ASSUMPTIONS AND DATA SOURCES

This appendix documents the assumptions and data used in the final run of the HCAS model for the 2023 Highway Cost Allocation Study. Data used in the final model run were collected between roughly November 2022 and April 2023. The final model run was completed and verified in June 2023.

Table 1 through Table 6 list assumptions in the HCAS Inputs Excel workbook that are used in the final run of the model. Table 1 and Table 2 have the HCAS Inputs workbook tab listed in the first column followed by the assumption name or brief description.

Like prior HCAS inputs workbooks, this workbook includes a Base VMT tab. Table 1 lists the assumptions used to develop the Base VMT tab in the inputs workbook. These assumptions are yellow-shaded cells in their respective workbook tabs. The key tabs that are linked to and build up the Base VMT tab are the VMT Growth, DMV VMT, MCTD VMT, Federal VMT, and Bus VMT tabs.

Table 2 lists the assumptions in the HCAS inputs workbook. Most of the assumptions listed in Table 2 correspond to yellow-shaded cells in their respective workbook tab.

Table 3 through Table 5 display the assumptions for studded tires, motor home weight classes, bridge splits, and initial mpg because these assumptions are tables or ranges, not single values.

Table 3 displays expenditures related to studded tires. It shows biennium expenditures by funding source, work type and facility class.

Table 4 displays the assumed 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 5 contains the assumed initial MPG, created from regression of the 2002 Vehicle Inventory and User Survey published by the U.S. Census Bureau. The Vehicle Inventory and Use Survey was discontinued after 2002.

Table 6 lists the files and sources of the data used in the 2023 Final HCAS model run.

TABLE 1. BASE VMT WORKSHEET ASSUMPTIONS

Tab	Assumption	Value
DMV VMT	Commercial Trucks & Buses Annual VMT per vehicle (10,001 to 26,000 weight class)	12,873
DMV VMT	Tow Truck Annual VMT per vehicle	22,527
DMV VMT	Farm Vehicle Annual VMT per vehicle	12,282
DMV VMT	Permanent Registration Annual VMT per vehicle	5,549
DMV VM	Charitable & Non-Profit Annual VMT per vehicle	7,556
DMV VMT	Motorhome Annual VMT per vehicle	3,798

See: HCAS Inputs 2023.xlsx

TABLE 2. HCAS MODEL USER-SPECIFIED ASSUMPTIONS

Tab	Assumption	Value	Justification/Source
General	Split of bridge expenditures across bridge reclassification work types	See Table 5	2002 OBEC Bridge Allocation Study
General	Base Year	2021	Ch. 2, pg. 15
General	Biennium	2023	Ch. 2, pg. 15
General	BondFactor	0.1472	Ch. 3, pgs. 21-22
General	Forecast Year (also, Model Year)	2024	Ch. 2, pg. 15
General	Percent of basic gallons that are diesel	5.5%	NA
General	Percent of RV gallons that are diesel	50%	NA
General	Percent of taxed gallons that are basic	92.49%	NA
MPG	MPG (initial) by weight class	See Table 6	Regression on 2002 VIUS data
Policy	Preliminary and Construction Engineering (and etc.) Share 1	55.95%	Ch. 3, pg. 17
Policy	Right of Way (and Utilities) Share 1	73.75%	Ch. 3, pg. 17
Policy	New Pavements-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	New Pavements-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Rehab-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Pavement and Shoulder Rehab-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Surface and Shoulder Maintenance-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 17
Policy	Surface and Shoulder Maintenance-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 17
Policy	Local Gov: Preliminary and Construction Engineering (and etc.) Share 1	55.92%	Ch. 3, pg. 19
Policy	Local Gov: Right of Way (and Utilities) Share 1	55.92%	Ch. 3, pg. 19
Policy	Local Gov: New Pavements-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: New Pavements-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Reconstruction-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Reconstruction-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Rehab-Flexible Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Pavement and Shoulder Rehab-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	Local Gov: Surface and Shoulder-Rigid Allocator/Share 1	3.99%	Ch. 3, pg. 19
Policy	Local Gov: Surface and Shoulder-Flexible Allocator/Share 1	5.43%	Ch. 3, pg. 19
Policy	All other Allocators Shares for work types not Prelim. Engineering, ROW, or Pavement	100%	Ch. 3, pgs. 17-20

TABLE 2 (CONTINUED). HCAS MODEL USER-SPECIFIED ASSUMPTIONS

Tab	Assumption	Value	Justification/Source
General	Gas Tax Avoidance Rate	3.53%	Ch. 3, pg. 26
General	Diesel Tax Evasion & Avoidance Rate	4.53%	Ch. 3, pg. 26
General	WMT Evasion Rate	9.4%	Ch. 3, pg. 26
General	Basic Diesel (Percent of basic VMT by diesel vehicles)	5%	
General	Taxed Diesel (percent of taxed gallons that are diesel)	10.5%	
General	RUAF Registration Adjustment	4.5%	NA
General	RUAF Reg. from 78001	14%	NA
General	RUAF Reg. from 96001	15%	NA
General	RUAF Reg. from 104001	71%	NA
General	Log truck miles empty	55%	Ch. 7, pg. 66
General	Split of studded tire expenditures across funding sources and work types	See Table 3	NA

See: HCAS Report; General, Policy and MPG tabs, HCAS Inputs.xlsx

TABLE 3. STUDDED TIRE ASSUMPTIONS

Funding	Work Type	Facility Class	Biennium Expenditures ($)	Distribution by Work Type
state	-	0	4,188,448[1]	100%
state	1	0	199,118	5%
state	11	0	3,318,633	79%
state	26	0	670,697	16%
local-state	-	-2	460,729[2]	100%
local-state	101	-2	21,903	5%
local-state	111	-2	365,050	79%
local-state	126	-2	73,777	16 %

See: General tab, HCAS Inputs.xlsx

[1] Figure 5.5, Review of Studded Tires in Oregon, Final Report, SPR 304-671, December 20, 2014, ODOT Research Section

[2] Equal to 11% of state expenditures (using state / local-state split, speed adjustment factor).

TABLE 4. BRIDGE SPLIT ASSUMPTIONS

Bridge Type	Work Type	Share
0	60	0.6849
0	61	0.2520
0	62	0.0000
0	63	0.0000
0	64	0.0631
1	60	0.6666
1	61	0.2999
1	62	0.0000
1	63	0.0000
1	64	0.0335
2	60	0.6849
2	61	0.2520
2	62	0.0000
2	63	0.0000
2	64	0.0631
3	60	0.7221
3	61	0.1697
3	62	0.0000
3	63	0.0514
3	64	0.0568
4	60	0.8713
4	61	0.1029
4	62	0.0000
4	63	0.0000
4	64	0.0258

See:General tab (Bridge Splits Table), HCAS Inputs.xlsx

TABLE 5. MPG ASSUMPTIONS (INITIAL MPG)

Declared	MPG	Declared (cont.)	MPG (cont.)
1	23.34	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

Declared	MPG	Declared (cont.)	MPG (cont.)
66,001	5.78	164,001	4.42
68,001	5.73	166,001	4.40
70,001	5.69	168,001	4.38
72,001	5.65	170,001	4.36
74,001	5.61	172,001	4.34
76,001	5.57	174,001	4.33
78,001	5.53	176,001	4.31
80,001	5.49	178,001	4.29
82,001	5.45	180,001	4.28
84,001	5.42	182,001	4.26
86,001	5.38	184,001	4.24
88,001	5.35	186,001	4.23
90,001	5.31	188,001	4.21
92,001	5.28	190,001	4.19
94,001	5.25	192,001	4.18
96,001	5.22	194,001	4.16
98,001	5.19	196,001	4.15
100,001	5.16	198,001	4.13
102,001	5.13	200,001	4.12

See: MPG tab, HCAS Inputs.xlsx

PROCESSING OF ORIGINAL DATA

The following section discusses data sets that require 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 or text files.

DMV Registration Data

DMV registrations by weight class and tax class are used to estimate the base year VMT in the DMV VMT tab in the HCAS Inputs workbook.R 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 "Motive Power."

DMV Motorhome Registrations

Motorhome VMT were estimated using motorhome vehicle counts from the DMV data with an assumed annual VMT. This table is available in the *DMV VMT* tab in the HCAS inputs workbook.

WMT Collections

The R code for the WMT Collection reports data first create the weight class and axle count variables and then creates the WMT summary table, which is pasted into the *MCTD VMT* tab in the HCAS inputs workbook.

Flat Fee Collection Reports

In previous studies, the cleaned Flat Fee Reports were obtained in a raw, database format. Since the 2015 Study, Flat Fee Reports were provided in a series of tabs/tables in an Excel workbook.

TABLE 6. 2023 HCAS DATA FILES AND SOURCES

Data	Source	File Name
Bridge Project Information	ODOT	HCAS Project Summary Rpt Final.xlsx
DMV Registration Data	ODOT	CurReg_122021_with_DataOne.csv
Federal Fleet Report	https://www.gsa.gov/policy-regulations/policy/ vehicle-management-policy/federal-fleet-report	2021 Federal Fleet Report. US General Services Administration (GSA).
FHWA Highway Statistics-Table MV7	https://www.fhwa.dot.gov/policyinformation/statistics.cfm	FHWA Highway Statistics-Table MV7 (2021): mv7.xls
FHWA Highway Statistics-Table VM2	https://www.fhwa.dot.gov/policyinformation/statistics.cfm	FHWA Highway Statistics-Table VM2 (2021): vm2.xls
Flat Fee Collections Reports	ODOT	OR_LOGS_100%_95%_90%_85%_80%_2021.xlsx, OR_S&G_100%_97%_95%_2021.xlsx, Final Report 2021 Flat Fee Study.pdf
OR HPMS Submittal Data	ODOT	HPMS_FULL_OR_2021.zip
Local Costs: Local Roads and Streets Survey	ODOT	2021 LRSS Master Combined City County.xlsm
Motor Carrier Registrations	ODOT	CCD Registered Plates for CY 2021.xlsx
Non-Project Costs	ODOT	Costs to Allocate and Projects Expenditures 2021-23 Final.xlsx
Pavement Factors	Roger Mingo, Mingo and Assoc.	Shr2 VMT v3 WIM Ext v4.xlsx
Project Costs	ODOT	HCAS Project Summary Rpt Final.xlsx
Studded Tire Expenditures	ODOT	Figure 5.5, Review of Studded Tires in Oregon, Final Report, SPR 304-671, December 20, 2014, ODOT Research Section, Tire Expenditure Forecast, Mar 2023
VMT Forecast	ODOT	HCAS 2022-2024 VMT estimate and forecast.xlsx
Revenue Forecast	ODOT	Transactions Revenues 2023-25_October 2022 Forecast.xlsx
RUAF Collection reports	ODOT	RUAF_2021.csv
Transit VMT: Tri-Met	ODOT	School Bus VMT Data.xlsx
Weigh-In-Motion Data	ODOT	WIM_2021_daily, .txt
WMT Collection Reports	ODOT	CCD WMT for CY 2021 Quarter 1, 2, 3, 4.xlsx

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APPENDIX F: PAVEMENT COST ALLOCATION FACTORS IN OREGON

BACKGROUND

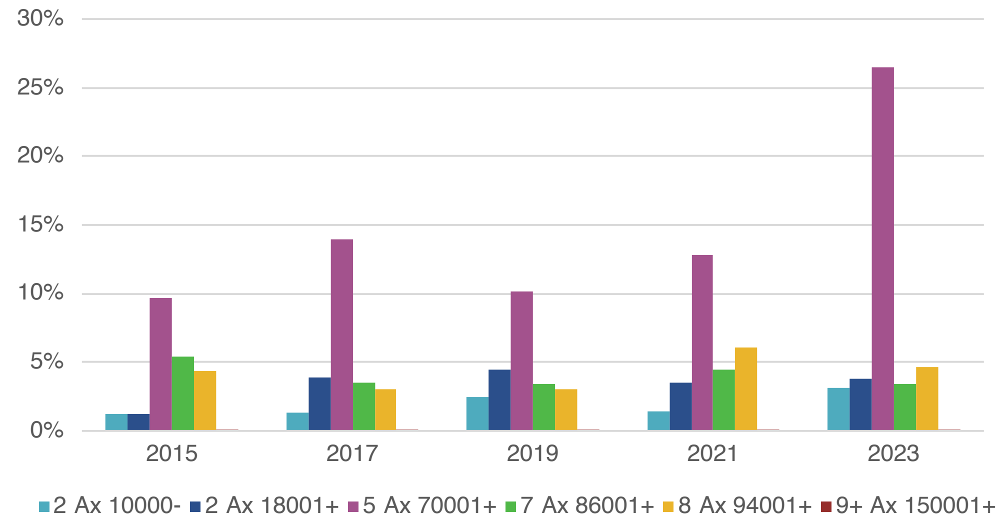
Highway Cost Allocation Studies in Oregon have used the same pavement load equivalence factors since 2011 and have all followed the same major steps in assigning pavement costs. Each study sees variations in cost responsibilities based on changes in highway expenditure estimates, vehicle travel estimates, and vehicle axle weight estimates. This summary compares the pavement cost shares for the current study to each of the previous four studies. The cost shares are applied to pavement cost expenditure estimates for each type of pavement to assign dollar costs to each vehicle class, but the assigned costs themselves are not included in this summary—only the shares of costs.

TYPICAL VEHICLES

In Oregon cost allocation studies, vehicles are divided into 100 operating gross vehicle weight (OGVW) groups on each of 12 highway types. One way to cut through the clutter of all these divisions in comparing results of different studies is to focus on a much smaller number of representative subgroups of vehicles.

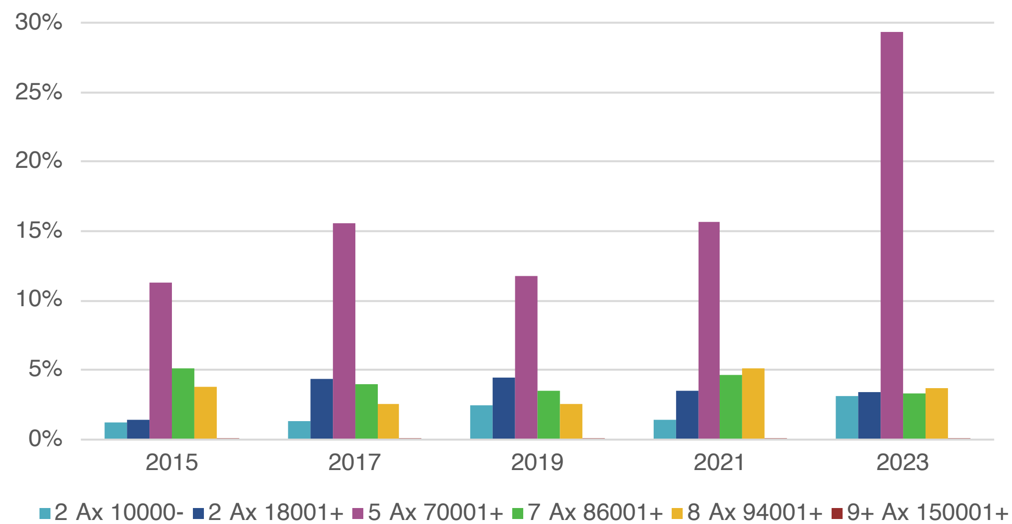
The following charts focus on six such subgroups: (1) two-axle vehicles operating at 10,000 lbs. and below (2 Ax 10000-), (2) two-axle vehicles operating between 18,001 and 28,000 lbs. (2 Ax 18001+), (3) five-axle vehicles operating between 70,001 and 80,000 lbs. (5 Ax 70001+), (F4) seven-axle vehicles operating between 86,001 and 96,000 lbs. (7 Ax 86001+), (5) eight-axle vehicles operating between 94,001 and 104,000 lbs.(8 Ax 94001+) , and (6) nine-axle-plus vehicles operating between 150,001 and 160,000 lbs. (9 Ax 150001+).

EXHIBIT 1: FLEXIBLE PAVEMENT SHARES OVER TIME BY WEIGHT AXLE COMBINATION, RURAL INTERSTATE, 2015–2023



Source: ECONorthwest, 2023 HCAS Model

EXHIBIT 2: RIGID PAVEMENT SHARES OVER TIME BY WEIGHT AXLE COMBINATION, RURAL INTERSTATE, 2015–2023



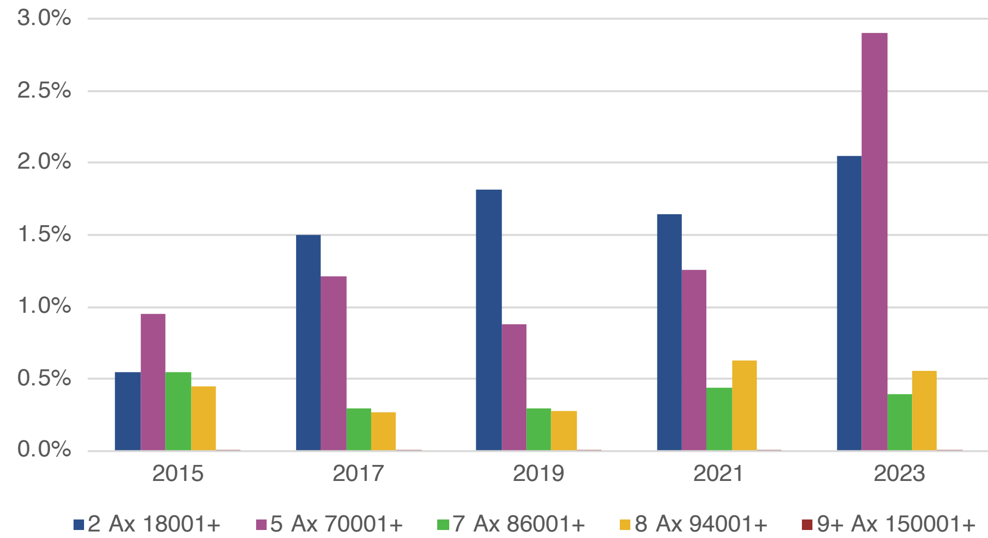
Source: ECONorthwest, 2023 HCAS Model

Note also that the 9+ Ax 150001+ group is barely visible, reflecting its relative size.

These two exhibits show somewhat higher shares for both flexible and rigid pavements on the rural interstate system for both the 2 Ax 10000- weight class, which grew from ~1 percent in 2015 to ~3 percent in 2023, and the 5 Ax 70001+ group, which grew from ~10 percent in 2015 to ~32 percent in 2023. These increases reflect (a) the continuing shift toward heavier passenger vehicles (as shown in the 2022 and 2023 WIM data used for the 2023 HCAS Model) in the case of the 2 Ax 10000- group and (b) a shift toward more travel by the 5 Ax 70001+ group, as seen in Exhibit 5.

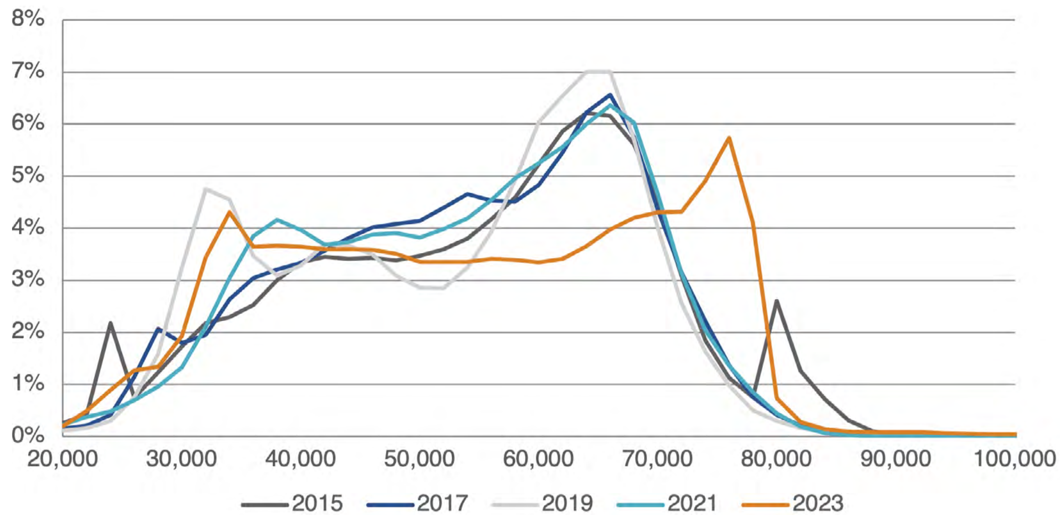
In fact, the shift toward more travel by the 5 Ax 70001+ subgroup shows up event more vividly when the overall weight distributions for all five-axle vehicles are compiled, as in Exhibit 6, where the shifting peak of the orange line demonstrates the increase in heavier 5-axle trucks on Oregon's highways.

EXHIBIT 3: VEHICLE MILES TRAVELED SHARES OVER TIME BY WEIGHT AXLE COMBINATION, RURAL INTERSTATE, 2015–2023



Source: ECONorthwest, 2023 HCAS Model

EXHIBIT 4: GROSS VEHICLE WEIGHT DISTRIBUTION FOR OPERATING 5-AXLE VEHICLES, RURAL INTERSTATE, 2015–2023



Source: ECONorthwest, 2023 HCAS Model

PAVEMENT FACTORS

Another way to compare results of previous HCAS studies is to display the pavement damage factors that are applied to various groups of vehicles. The pavement damage analysis tool that has been used by Oregon's HCAS since 2013 applies a set of load equivalence factors to each axle across all vehicles using the pavements in a given highway class, sums these factors, and derives a share of damage for each operating weight group and axle configuration. The result is a set of pavement factors that show the relative costs attributable to each vehicle subgroup.

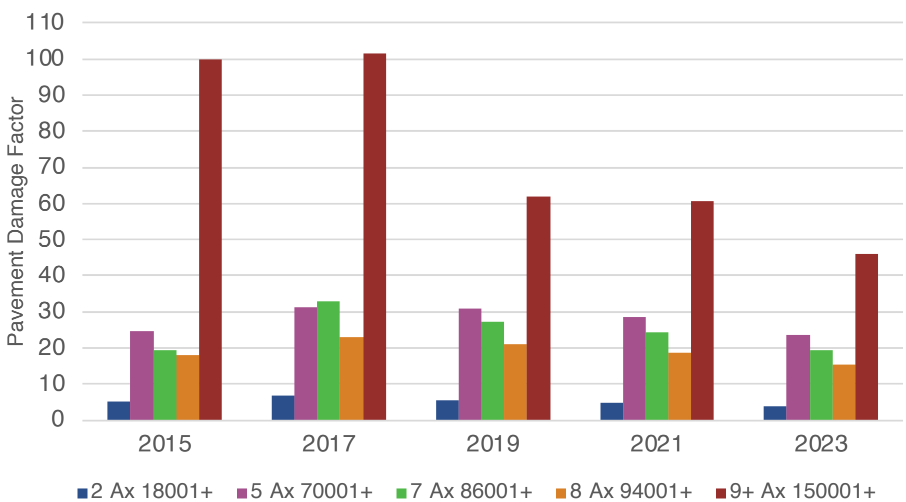
In the charts that follow, we use the five heaviest subgroups of vehicles that we used in the previous section. Instead of displaying shares of costs, show the relative costs for each of the sample subgroups.

Note the consistent pattern over all the studies, but the slight decrease in the magnitude of the factors for the 2023 study. This is likely due to the increasing axle weights shown in the most recent WIM data, which has the effect of reducing the shares for any one axle.

AXLE CONFIGURATION SHARES

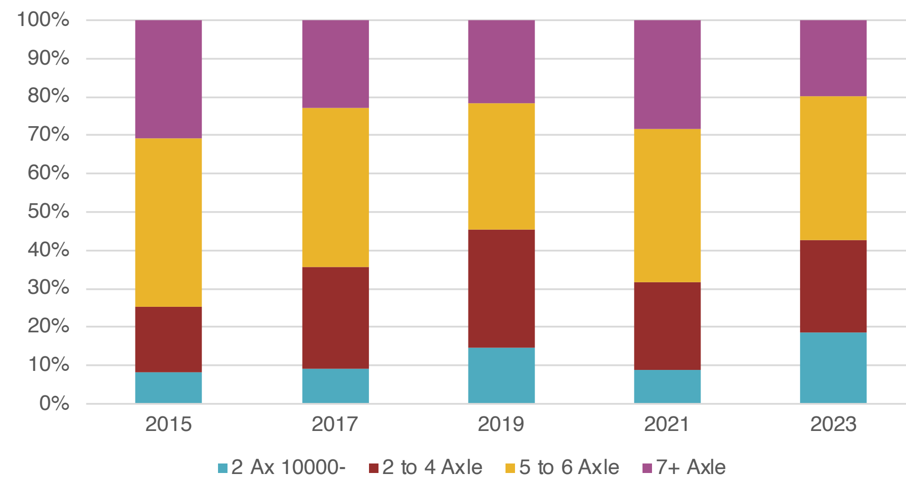
A final way of comparing results that we have used in this report is to display the total pavement shares attributable to vehicles in broad groups, based on number of axles. The charts below show how pavement shares are divided among four groups: two-axle vehicles operating at 10,000 lbs. and under, other two to four-axle vehicles, five and six axle vehicles, and seven-or-more-axle vehicles. Since 2015, the share of basic vehicles, or two-axle vehicles operating at 10,000 lbs. and under, has increased from under 10 percent to nearly 20 percent on urban other principal arterial roads, a trend that is also seen across other road classes. This finding is likely an improvement in data rather than a change in the actual share of vehicles on various parts of the state road network.

EXHIBIT 5: PAVEMENT DAMAGE FACTOR RELATIVE COST ACROSS WEIGHT AXLE COMBINATION, RURAL INTERSTATE, 2015-2023



Source: ECONorthwest, 2023 HCAS Model

EXHIBIT 6: PAVEMENT SHARES ACROSS AXLES, URBAN OTHER PRINCIPAL ARTERIAL, 2015-2023



Source: ECONorthwest, 2023 HCAS Model

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APPENDIX G: A PRELIMINARY EXAMINATION OF I-205 TOLLING

BACKGROUND

In the 2001 Oregon Highway Cost Allocation Study, the concept of efficient fee-based cost allocation was introduced. And the 2015 Oregon Highway Cost Allocation Study outlined a demonstration program to convert its Highway Fund revenue instruments to efficient fee instruments. Instead of estimating costs imposed by forecasting highway-agency expenditures and then allocating those expected expenditures to vehicle weight classes, the efficient fee approach forecasts the revenues that vehicles in each weight class would pay if a set of revenue instruments were to charge each vehicle for the costs it imposes for each mile it travels, given the time and place of travel and the weight and other characteristics of the vehicle.

An efficient vehicle fee is about more than just paying for new infrastructure. An efficient fee recovers costs from users directly. Those costs relate to the maintenance and operation of existing infrastructure and services and new infrastructure needs that result from growing transportation demand. One strategy for financing highway infrastructure that can be part of an efficient-fee approach is the application of tolls. Since 2015 the Oregon Department of Transportation has developed a toll program with the objective of meeting the goal of improved travel by managing traffic flow while helping to raise revenue for infrastructure improvements.

This issue paper examines how implementation of tolls for purposes of highway finance might influence the outcome of future cost allocations and revenue attributions in the state of Oregon.

OPTIMAL TOLLS & TOLL OBJECTIVES

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

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

But in reality, the costs imposed by users vary considerably over time and space. The premise of congestion-based tolling (also called peak-period or variable pricing or tolling) is that this incorrect pricing leads to an over-consumption of certain types of transportation services (i.e., congestion) and an under-consumption of other transportation services. Correct pricing can reduce this problem. Conventional road finance exacerbates rather than ameliorates the problem. A low charge on all mileage allows excessive congestion during peak periods. While the congestion prompts road authorities to build new capacity, the low charges cannot cover the costs.

Tolls can be levied to reduce existing congested conditions or to raise revenues. Often both objectives are pursued to a degree. However, a toll rate that is designed to maximize revenue will not minimize congestion, or vice versa. In either case, if financing of highways through road use charges is to become a more generally usable approach, it would need to be responsive to a dynamic set of performance and investment conditions, such that:

- Tolls are levied on existing capacity based on the costs the user imposes. As vehicle use in a corridor increases, so do the toll rates, which manages growth in congestion.
- Revenues accrue over time and capacity is added where and when revenues are sufficient to justify investments.

A congestion-management approach to tolling means that toll rates can be lower after capacity is added since the tolls are not designed to meet a revenue target. If alternative routes also have cost-based tolls, then diversion is minimized, and revenue yield is easier to predict. Thus, the entire enterprise is a sound platform for long-term investment and growth.

EVALUATING THE I-205 TOLL PROJECT

This issue paper, however, is focused on evaluating the potential cost-allocation implications of tolling in the I-205 corridor at and approaching the Abernathy Bridge. That toll program is designed to finance corridor improvement while also retaining some variable toll rates in hopes of alleviating congestion and providing a lower toll cost option for corridor users during off-peak travel periods. In this paper, our concern is narrowly defined as the question of whether the shares of incremental costs allocated to different classes of highway users (light-duty versus heavy-duty vehicles) are similar to the shares of toll revenues that are paid.

Our approach to evaluating this question necessarily relies upon a current implementation of the HCAS model and reporting framework. However, tolls in the I-205 corridor will not be levied during the upcoming biennium. So, the first step in the evaluation is determining the methods for incorporating information about future tolling within the existing HCAS model. The steps are as follows:

1. Establish a baseline set of equity ratios from the current HCAS model for the 2023-25 biennium.
2. Identify an estimate of toll revenues appropriate for inclusion in the HCAS model.
3. Include in the HCAS model a list of projects and project costs associated with the I-205 toll program.
4. Assign work types to the I-205 toll program projects.
5. Calculate a new set of equity ratios that reflect both toll revenue and toll-program projects and costs.

The source of information about toll-revenue estimates is the I-205 Toll Project Level 2 Toll Traffic and Revenue Study Report released in October of 2022. Information about the I-205 projects and project costs, and their work types, was provided by the Oregon Department of Transportation.

I-205 TOLL PROJECT

ODOT is proposing to implement tolls on the Abernethy Bridge and Tualatin River Bridges of I-205 to generate funding for the I-205 Improvements and to manage congestion on I-205 between Stafford Road and Oregon Route 213. The I-205 Toll Project is located on I-205 approximately five miles south of Portland and crosses through the jurisdictions of Oregon City, West Linn, and Clackamas County. Exhibit 1 illustrates the I-205 Toll Project and the locations for placement of toll gantries near the Abernethy Bridge and the Tualatin River Bridges.

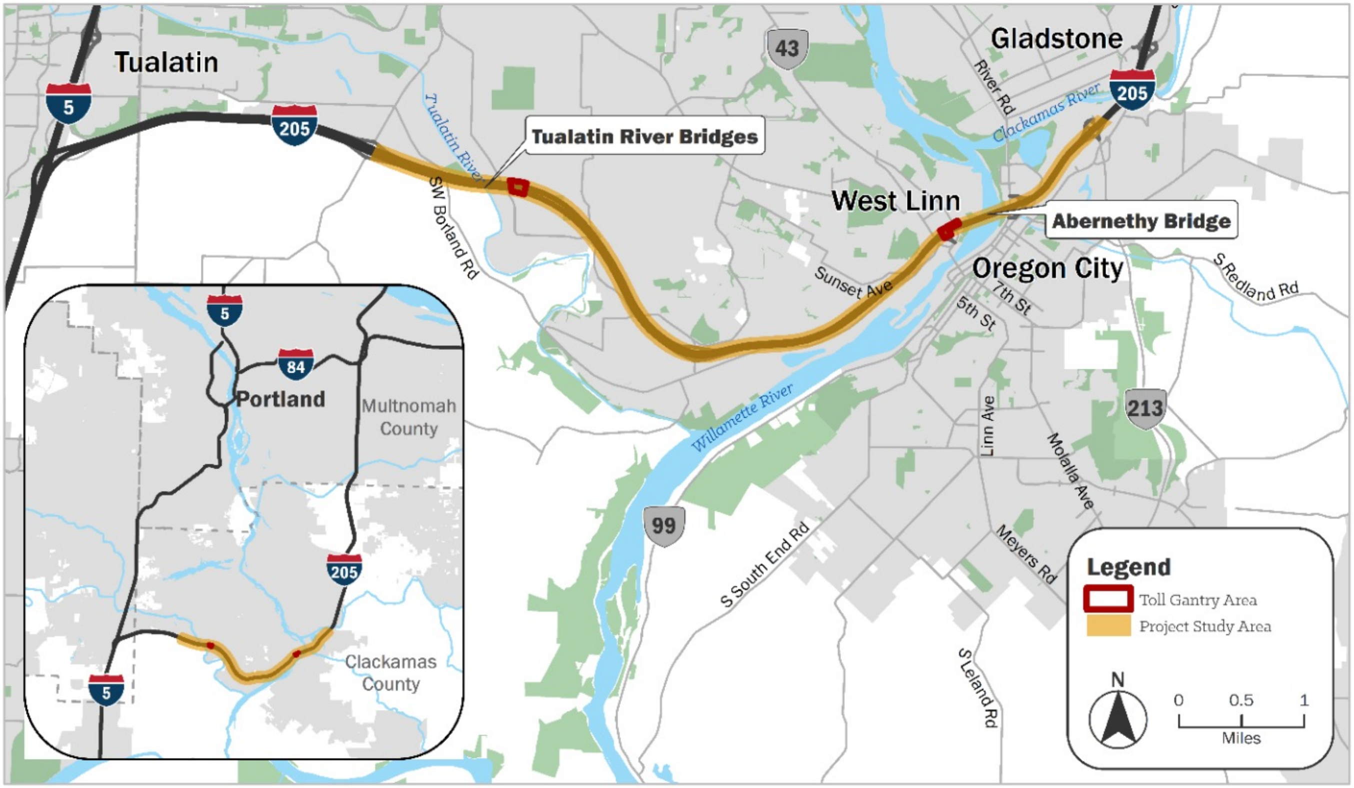
The I-205 Improvements Project includes the following project elements:

- Constructing seismic upgrades to eight bridges along I-205
- Constructing a third lane in each direction of I-205 between Stafford Road and OR 99E and constructing a northbound auxiliary lane from OR 99E to OR 213
- Constructing interchange improvements.

The I-205 Improvements Project would be constructed in two phases (Exhibit 2). Phase 1 would involve multiple contracts and subphases (A – D). In 2021, HB 3055 provided state financing tools that allow construction of Phase 1A to begin in 2022, prior to toll implementation. Phase 1A includes reconstructing the Abernethy Bridge and adjacent interchanges at OR 43 and OR 99. Funding through toll revenues is necessary to complete the remaining phases of the I-205 Improvements Project:

- Phase 1B (OR 99E to OR 213)
- Phase 1C (Sunset Bridge to OR 43)
- Phase 1D (10th Street to Sunset Bridge)
- Phase 2 (Stafford Road to 10th Street, and reconstruction of the Tualatin River Bridges)

EXHIBIT 1: I-205 TOLL PROJECT LOCATION



Source: I-205 Toll Project Level 2 Toll Traffic and Revenue Study Report, October 2022

EXHIBIT 2: I-205 TOLL PROJECT PHASES

Source: I-205 Toll Project Level 2 Toll Traffic and Revenue Study Report, October 2022

TRAFFIC AND REVENUE STUDY

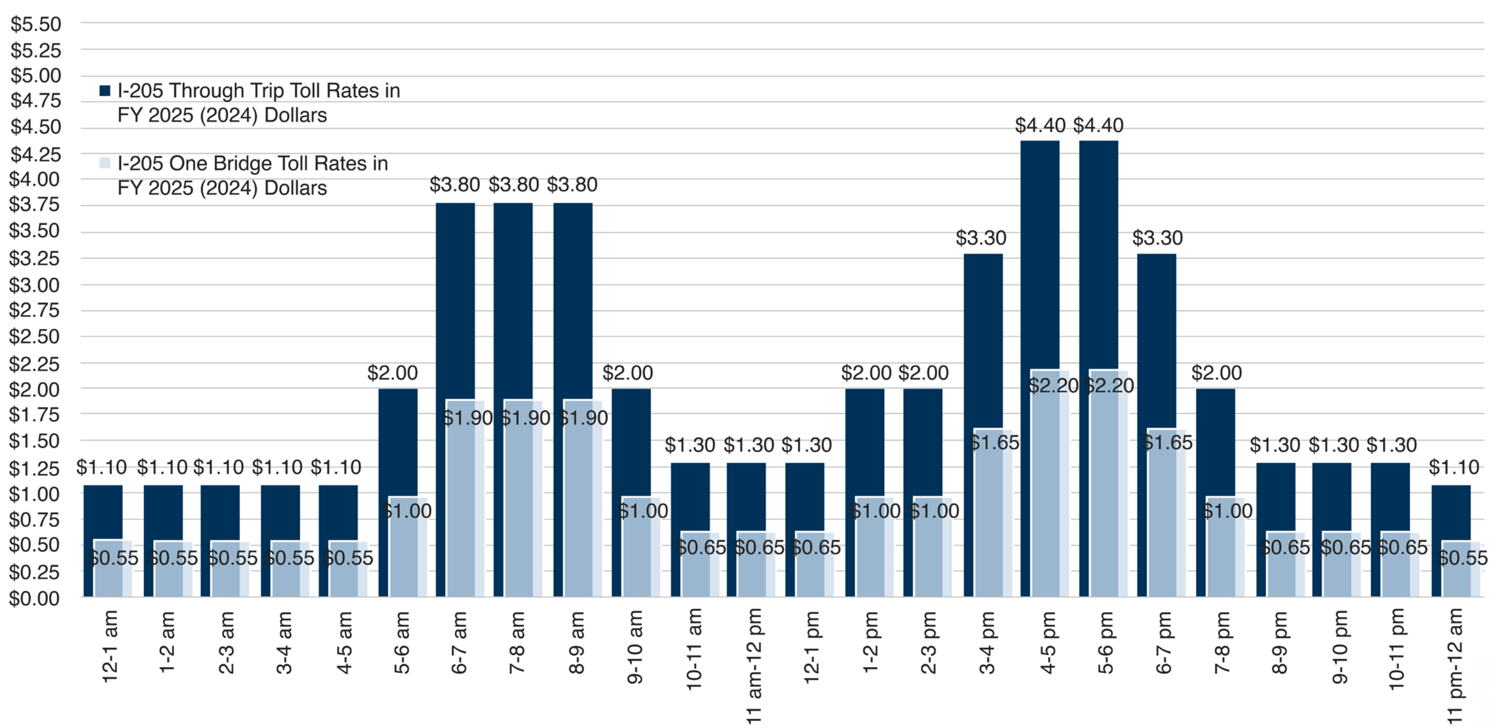
The I-205 Toll Project Level 2 Traffic and Revenue (T&R) Study is the basis for estimates of toll revenues that are used in this issue paper. The Traffic and Revenue Study begins with the representation of the toll project within the Portland Metro regional travel demand model. The study was conducted by a team comprised of staff from Metro, ODOT, and a WSP Consultant Team.

Metro developed and maintains both the regional travel demand model and dynamic traffic assignment models for use on the I-205 Toll Project. These model data include the existing base year (2015) and future years (2027 and 2045) No-Build and Build models. The Consultant Team applied the models to conduct analysis and sensitivity tests, and to derive specific model outputs for analysis purposes. Model volumes from both the demand model and peak-period volumes from the DTA model were post-processed to obtain the projected 2027 and 2045 weekday traffic volumes used for preparing the annual toll traffic and revenue projections.

The traffic volumes and toll rates (see Exhibit 3 below) that are part of the travel demand forecast were then used in the Traffic and Revenue Study to estimate toll transactions and gross and net toll revenues. The toll rates assumed in the Traffic and Revenue Study varied by time of day but also across light-duty vehicles, medium trucks, and heavy trucks. Medium trucks see a toll that is two times the value of the base toll rate while heavy trucks see a toll that is four times the value of the base toll rate.

The T&R Study estimated toll transactions and gross revenues for each of the above vehicle classes and also estimated the various uncollectable revenue and toll transaction fees that permit the estimation of a net revenue finding.

EXHIBIT 3: I-205 TOLL RATES



Source: I-205 Toll Project Level 2 Toll Traffic and Revenue Study Report, October 2022

TOLL REVENUE ATTRIBUTION

For this issue paper, the I-205 Toll Project toll transactions, gross revenues, and net revenues for each vehicle class are used as a basis for the toll revenue attribution to the various HCAS vehicle categories. Toll revenue attribution is handled as a post-processing step once the HCAS model has been implemented.

Within the I-205 Toll Project Level 2 Traffic and Revenue Study, the gross revenue is first adjusted for uncollectable revenues. This adjusted toll revenue is the starting point for this issue paper's revenue attribution. Next, a set of toll system-related fees is removed from the adjusted revenue estimates to arrive at net revenues. The fees estimated in the T&R Study are apportioned according to the share of toll transactions that are associated with each vehicle class for the purposes of this issue paper.

The T&R Study projects toll revenue estimates through the year 2060. But for our purposes, we require early-year revenue estimates that coincide as closely as possible with the current HCAS model implementation timeline (2023-25). Since early-year estimates include a tolling ramp-up period (a period where toll system users adjust to the new system) we have chosen revenue estimates that occur just after the ramp-up has concluded. This set of assumptions is a reasonable basis for a preliminary examination of tolling within HCAS that preserve the basic logic of the toll program while conforming to HCAS modeling requirements that otherwise reflect the most recent other HCAS cost and revenue inputs and assumptions.

EXHIBIT 4: TRAFFIC AND REVENUE STUDY INPUTS TO HCAS

Annual Average Adjusted Gross and Net Toll Revenue (millions)			
	Basic Vehicles	Medium Truck	Heavy Truck
Adjusted Revenue	$71.86	$ 9.51	$22.83
Toll System Costs	-40.73	-2.69	-3.24
Net Revenues	31.13	6.81	19.60

Source: I-205 Toll Project Level 2 Toll Traffic and Revenue Study Report, October 2022

As a sensitivity test, we examined the average gross toll and net toll revenues over the full T&R forecast and determined that the share of revenues by vehicle class does not change substantially.

TOLL PROJECT COST ALLOCATION

The I-205 Corridor investments are to be financed, in part, with toll revenue. The initial phase of investment is the replacement of the Abernathy Bridge. As described above, subsequent phases of investment include constructing a third lane in each direction of I-205 between Stafford Road and OR 99E and constructing a northbound auxiliary lane from OR 99E to OR 213, improving interchanges, and reconstructing the Tualatin River Bridges.

Total additional investment beyond the current Phase 1A will total $697 million. ODOT has indicated that the expenditures can be allocated to various types of work activities in the following manner:

- Engineering, 20% (this includes construction engineering)
- ROW/utilities, 5%
- New structures (retaining walls), 2%
- Replacement structures, 7%
- Roadside improvements, 30%
- Safety improvements, 5%
- Bike/ped improvements, 1%
- Bridge replacement with capacity (Tualatin River Bridges). 20%
- Structures rehabilitation: 10%

In addition, there are toll system deployment costs of $84 million that are not otherwise accounted for in the T&R study gross to net revenue data that is part of our revenue analysis.

Much in the same way that toll revenues will not be collected during the 2023-25 biennium, these project costs will likewise be incurred in the future. Similarly, in order to preserve the basic logic of the toll program while conforming to HCAS modeling requirements that otherwise reflect the most recent other HCAS cost and revenue inputs and assumptions, we include these project costs in the current HCAS model. However, since the project costs are large and will be supported through bond sales, we include the costs as bonded projects so that only annual bond payments are included in the comparison with toll revenues.

FINDINGS

The test of the I-205 Toll Project within the HCAS model is necessarily an incremental analysis that builds upon the base 2023 HCAS model and results. In order to make this analysis feasible, the actual details of the investment—including when projects are built (or costs are incurred) and when tolls are paid and revenues are collected—have been modified. In short, the analysis is equivalent to imagining that the toll project has already been built and toll operations have begun at the beginning of the 2023-25 biennium. This assumption is a necessary abstraction in order to make the HCAS analysis feasible but it does not fundamentally alter the equity implications and findings.

This paper examines how toll operations might be expected to affect the equity of highway finance by examining cost responsibility and revenue attribution across three toll-paying vehicle classes (light-duty, medium trucks, and heavy trucks). Within the HCAS model, these vehicle classes are based on vehicle weight (under 10,000 lbs., 10,000 to 26,000 lbs., and above 26,000 lbs.). The toll system is expected to classify vehicles by shape rather than weight, but nonetheless, the two classification systems are similar.

The base 2023 HCAS results are included in Exhibit 5 below. The exhibit displays cost shares, revenue shares, and equity ratios for the three vehicle classes. Exhibit 6 includes the same metrics for the 2023 HCAS model with the inclusion of the I-205 toll program.

EXHIBIT 5: BASE 2023 HCAS: COST SHARES, REVENUE SHARES, AND EQUITY RATIOS

BASE 2023 HCAS			
	Basic/ Light	Medium Truck	Heavy Truck
Cost Share	72.7%	3.3%	24.0%
Revenue Share	63.9%	3.5%	32.6%
Equity Ratio	0.878	1.076	1.358

Source: ECONorthwest, 2023 HCAS Model

The comparison of Exhibits 5 and 6 demonstrates the equity implications for the entire system of highway finance. With the inclusion of the I-205 toll program medium and heavy trucks pay a higher share of user fees than in the Base case. The share of costs allocated to medium and heavy vehicles, with the inclusion of the I-205 toll program, decline slightly as compared with the Base case. As a result, the equity ratio for basic vehicles with the inclusion of the I-205 toll program declines and the equity ratios for medium and heavy vehicles increase.

EXHIBIT 6: 2023 HCAS WITH I-205 TOLL PROGRAM: COST SHARES, REVENUE SHARES, AND EQUITY RATIOS

2023 HCAS with I-205 Toll Program			
	Basic/ Light	Medium Truck	Heavy Truck
Cost Share	73.3%	3.2%	23.5%
Revenue Share	63.5%	4.0%	32.5%
Equity Ratio	0.866	1.225	1.386

Source: ECONorthwest, 2023 HCAS Model

And finally, Exhibit 7 includes results from examining just incremental costs and revenues from the I-205 toll program. These findings demonstrate whether the toll program, on its own, results in tolls being paid in proportion to the costs assigned to each class of vehicles. Based on the current analysis assumptions, basic or light-duty vehicles are responsible for 93 percent of the toll program costs while paying 58 percent of the net toll revenues, resulting in an equity ratio of 0.627. The equity ratios for medium trucks and heavy trucks are 8.577 and 5.230 respectively.

EXHIBIT 7: INCREMENTAL I-205 TOLL PROGRAM: COST SHARES, REVENUE SHARES, AND EQUITY RATIOS

Incremental Results for the I-205 Toll Program			
	Basic/ Light	Medium Truck	Heavy Truck
Cost Share	92.8%	1.2%	6.0%
Revenue Share	58.2%	10.3%	31.5%
Equity Ratio	0.627	8.577	5.230

Source: ECONorthwest, 2023 HCAS Model

POTENTIAL IMPLICATIONS

An ex-ante evaluation of the I-205 toll program has limitations, especially given the assumptions that need to be made in order to include toll project costs and revenues in the 2023 HCAS model. As such, these findings need to be considered with those limitations in mind. The potential implications for equitable highway finance are a best guess based on existing plans for tolling implementation as included in the I-205 Phase 2 Traffic and Revenue Study.

The expectation is that toll rates established for the Portland metro region will vary according to a time-of-day schedule based on congestion relief goals, revenue needs, and public input. However, actual toll policy in Oregon is set by the Oregon Transportation Commission and is likely to be set about six months before tolling begins.

This current analysis suggests that basic/light-duty vehicles may not contribute to toll revenues proportionate to their cost responsibility, and that medium and heavy trucks may contribute to toll revenues in excess of their cost responsibility. A reasonable question is what toll policy could yield equity ratios that are closer to 1.0 for each vehicle class?

The assumptions used in the I-205 T&R Study are that medium trucks pay a toll that is twice the base toll rate and that heavy trucks pay a toll that is four times the base toll rate. An alternative approach is to set toll rates that are based on each vehicle's passenger car equivalency (PCE). PCEs reflect the fact that larger vehicles take up more space on the road and also that heavier vehicles have different performance in terms of acceleration, vehicle spacing, and deceleration. These differences in performance determine how each vehicle contributes to potential traffic congestion. So, tolls that are designed to manage traffic flow might be reasonably based on vehicle PCE. Under typical conditions basic/light-duty vehicles have a PCE of 1.0, medium trucks often have a PCE value of around 1.1, and heavy trucks can have PCE values of approximately 1.5.

Tolls based on base toll rate multipliers that are PCE values would yield lower revenue for medium and heavy trucks than is true in the Base case. A simplistic adjustment of toll revenues based on this policy yields an equity ratio for basic/light-duty vehicles of around 0.9. A more formal analysis of alternative toll policy requires re-running demand models and further T&R analysis and would also result in higher toll-paying truck volumes in response to lower toll rates. And in turn, a larger portion of toll operating costs and fees would be attributed to truck traffic. In summary, it is reasonable to expect that a toll policy based on PCE would bring the equity ratio for basic/light-duty vehicles closer to 1.0 for the I-205 toll program.

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