ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ99-477(1)

1999 UPDATE OF THE ARIZONA HIGHWAY COST ALLOCATION STUDY

Final Report

Prepared by:
Jason Carey
P.O. Box 87862
Phoenix, AZ 85080

August 1999

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-AZ-99-477(1)		

4. Title and Subtitle	5. Report Date
1999 Update of the Arizona Highway Cost Allocation Study	August 1999
	6. Performing Organization Code

7. Authors	8. Performing Organization Report No.
Jason Carey	

9. Performing Organization Name and Address	10. Work Unit No.
Jason Carey , P.O. Box 87862, Phoenix, AZ 85080	11. Contract or Grant No. SPR-PL-1-(55) 477

12. Sponsoring Agency Name and Address	13.Type of Report & Period Covered
ARIZONA DEPARTMENT OF TRANSPORTATION **206 S. 17TH AVENUE** **PHOENIX, ARIZONA 85007** Project Manager: John Semmens	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

The purpose of this report was to update the Arizona highway cost allocation study and to evaluate the alternative of using the new FHWA cost allocation model as a replacement.

The update revealed that the repeal of Arizona's weight-distance tax has led to a decrease in the payments made by the largest vehicles. As a result, these vehicles are now projected to pay less than their full cost responsibility over the 1999 through 2003 program years. Meanwhile, lighter vehicles will continue to pay more than their full cost responsibility over this same time period.

Efforts to use the new FHWA cost allocation model were thwarted by the requirement for data inputs that are not readily available. This data requirement argues against using this new model. It will not be a tool that is easy for state DOTs to employ in trying to estimate cost responsibilities and payment ratios by vehicle classes and weights. As an alternative, this project developed a simplified model that provides reasonable estimates of cost responsibility ratios. The simplified model uses readily available data and can be implemented by state DOTs without the assistance of external consultants.

It is recommended that ADOT use the simplified model for future highway cost allocation updates and that the previously planned "phase 2" of this project be modified to entail a FY 2000-2004 update using both the existing Arizona highway cost allocation model and the simplified model and that a detailed users' manual for the simplified model be drafted for future reference.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
cost allocation, tax equity	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	

19. Security Classification	20. Security Classification	21. No. of Pages	22. Price
Unclassified	Unclassified	82	

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

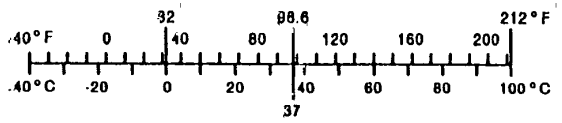
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3

		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements



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Summary of Key Findings

The lack of direct charges for use of the roads creates the need for states to perform Highway Cost Allocation Studies in order to answer two basic questions: (1)are highway users, as a group, paying the full cost of the roadways and (2)is each class of vehicle paying its fair share.

With 100% representing a perfect match between cost responsibility and tax payments, for the extended period (FY 1988-2003) covered by highway cost allocation study updates in Arizona, highway users, as a group, are estimated to have paid about 98% of the cost of the roadways. Among the various classes of highway users, pick-up trucks and sport utility vehicles are estimated to be paying more than their fair share (123%). Heavier vehicles are estimated to be paying less than their fair share.

Table 8: Cumulative Totals for Fiscal Years 1988-2003
(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$11,323.2	$11,643.0	97%
Pick-up Trucks/SUVs	$5,948.9	$4,829.1	123%
Buses	$113.2	$168.2	67%
Single Unit Trucks	$1,533.6	$1,967.5	78%
Combination Trucks	$6,435.1	$7,213.8	89%
Totals	$25,354.0	$25,821.5	98%

The new highway cost allocation model under development by the FHWA was found to be unsuitable for use in Arizona at this time. This new model is unfinished and behind schedule in its development. It also requires the input of data that ADOT does not have. It would require significant effort or the intervention of external consultants to create this input data from existing internal ADOT sources.

The existing ADOT highway cost allocation model was found to have some serious limitations. Its internal workings are driven by obsolete FORTRAN programming language. Many of the data relationships are “hard wired” and not easily adjusted for changes in tax rates, traffic, or expenditure categories. Continued use of this model will be cumbersome.

Given the unusability of the new FHWA model and the growing obsolescence of the ADOT highway cost allocation model, this project undertook the development of a simplified highway cost allocation model.

The simplified model assigned construction costs based on the premise that in urban areas, these costs are driven primarily by the need to provide sufficient roadway capacity, while in rural areas, these costs are driven primarily by the need to provide pavements of sufficient strength to

handle heavy vehicles. Consequently, in urban areas, costs were allocated based on vehicle miles of travel, while in rural areas, costs were allocated based on vehicle axle weights per mile driven.

While there were some differences between the ADOT highway cost allocation model and the simplified model in the results generated by vehicle class, the outcomes for the dominant classes of highway users were similar. The results for FY 1999-2003 are shown in the table below. Both models show lighter vehicles paying more than their cost responsibility and combination trucks paying less than their cost responsibility. Since these classes of vehicles account for about 90% of costs and revenues, the utility of the simplified model as a "macro" policy tool appears warranted.

Table 44: Equity Ratios and Comparison of Simplified Model to ADOT HCAS Results

Vehicle Class	Equity Ratios	
	Simplified Model	ADOT HCAS Model
Autos	133%	130%
Pick-ups/SUVs	145%	174%
Buses	93%	90%
Single Unit Trucks	141%	90%
Combination Trucks	81%	93%
Total	120%	120%

The evidence seems to indicate that adjusting highway user tax rates to increase the revenues collected from heavier vehicles, while decreasing revenues from lighter vehicles may be warranted from an equity standpoint. In this regard, recent legislative action to reduce the vehicle license tax would appear to be proceeding in the right direction.

I. Introduction to Highway Cost Allocation

What Is a Highway Cost Allocation Study?

A highway cost allocation study (HCAS) is an attempt to compare revenues collected from various highway users to the expenses incurred by highway agencies providing facilities for these users. Only revenue directly attributable to taxes paid by highway users for the use of the highways is included on the revenue side of the equation. In Arizona, these revenues include gasoline and diesel fuel taxes, motor carrier fees, vehicle license and registration fees, and other miscellaneous fees. The revenue side of the equation does not include non-user taxes that may be spent on highways. The chief examples of non-user taxes spent on highways in Arizona include the sales taxes that are spent by the Arizona Department of Transportation (ADOT) on the freeway system in Maricopa County and property taxes and lottery receipts spent by local governments on roads and streets.

The expenditure side of the HCAS equation includes all outlays for roads, regardless of the source of these funds. These expenditures stand as a representation of what it costs to serve the needs of highway users. For the purpose of this HCAS update for Arizona, actual planned and estimated expenditures for the five-year period spanning 1999 to 2003 were used. That is, the projected amounts to be spent are the amounts that are attributed to various classes of vehicles using the highways in order to generate the cost responsibility side of the equation. What this means is that the HCAS is not a "needs" study. It does not presume to evaluate how much money should be spent on highways. It merely allocates responsibility to various classes of highway users for the amounts of money the various government agencies plan to spend on highways.

Why Do We Need a Highway Cost Allocation Study?

The purpose of an HCAS is to compare revenues and costs for various vehicle classes to provide information that will enable lawmakers to assess the equity of the existing highway user tax structure and determine whether changes are needed. The basic premise is that users ought to pay an amount sufficient to cover the cost incurred by highway agencies in providing the facilities needed by these users. Likewise, users should not have to pay more than it costs to provide the facilities they need.

An HCAS must be undertaken because of the indirect nature of how highway user taxes and fees are collected. In the marketplace, businesses do not have to perform cost allocation studies because customers are charged directly for the product or service the businesses provide. Equity is more easily determined. If the customer feels the price is equitable, the customer buys the product. Highway user taxes, for the most part, though, are assessed on fuel, the value of the vehicle, or in some other less direct way. Determining whether the amounts of taxes paid are equitably matched to the costs is,

therefore, more complicated. It is to try to resolve this more complicated problem that HCASs have been devised.

How is a Highway Cost Allocation Study Done?

The expenditures in the five year program and the local government highway budgets are analyzed to determine what shares of these outlays ought to be attributed to each class of vehicle. Basically, costs related to wear-and-tear (like repair of damaged pavement) and vehicle weight (like the structural strength of bridges) are mostly attributed to heavy vehicles. Costs related to capacity (like the number of lanes on an urban freeway) are mostly attributed to the passenger automobiles causing the peak period surges in traffic volume.

Each vehicle is allocated a share of the costs based on the type of highway expenditure mentioned in the previous paragraph and the total vehicle miles of travel (VMT) on the various types of highway by each vehicle class. For this study, vehicles have been grouped into five classes: autos, pick-ups/SUVs, buses, single-unit trucks, and combination trucks. The data are also portrayed by vehicle weight groupings as well.

Obviously, it could be argued that the variation of vehicles within classes is large. For example, among autos there are vehicles twice as fuel efficient as other vehicles. These more efficient vehicles will pay half as much gasoline tax per mile of travel than the less efficient vehicles. Similarly, newer, more expensive cars will pay a much larger vehicle license tax than older, lower-valued cars. Yet, there is no significant difference in cost responsibility for these vehicles from the standpoint of the highway agencies. Consequently, it is likely that from a cost responsibility perspective, there will be inevitable inequities in the way different vehicles are assessed for their use of the highways. Nevertheless, crude as it may be in treating vehicles within the class groupings, an HCAS is the best we can do short of electronically tracking and billing each separate vehicle for use of the highways. Until we are ready to use such electronic technology, basing user tax rates on HCASs will move us closer to equity than establishing user tax rates without regard to cost responsibility.

Who Does Highway Cost Allocation Studies?

About two-thirds of the states do some kind of highway cost allocation study. Some have in-house staff at the Department of Transportation conduct the study. Others hire consultants to perform the study. The original Arizona HCAS was performed by a consultant and published in January of 1993. An update was subsequently prepared by ADOT staff in 1996. This update is being prepared by ADOT with the assistance of an Arizona State University graduate student.

II. The ADOT Highway Cost Allocation Model

The original Arizona Highway Cost Allocation Model was created by SYDEC, Inc. for the Arizona Department of Transportation in 1993. The model uses a series of FORTRAN programs to allocate revenues and cost responsibilities among vehicle classes based on a variety of print file and database inputs. Print files are generated by several spreadsheets that tabulate expenditures, revenues and tax rates, registration and vehicle characteristics, and vehicle miles of travel by vehicle type and functional class of roadway.[1] The basic structure of the model is discussed below, and a detailed methodology for updating the model is provided in Appendix A of this report.

Revenue Attribution

Revenues collected are broken down for the purpose of the cost allocation model based on several criteria. State and federal fuel tax revenues are attributed based on estimates of VMT on Arizona roadways and fuel economy of each vehicle class. State registration fees and federal use tax are attributed using the annual fees applicable to vehicles depending on registered weight. Estimated percentage of annual travel in Arizona is used to adjust revenue estimates for trucks operating in several states. State motor carrier taxes are now attributed to vehicles depending on registered weight, with varying flat fees assessed on all weight categories.

State vehicle license and Federal truck and trailer taxes are attributed to vehicle classes using estimates of annual new vehicle sales and prices, with sales for each vehicle class estimated using national sales data. Federal tire tax fees are attributed to heavy vehicles in proportion to the product of VMT and average number of tires. Oversize permit fees are attributed to heavy single-unit and combination trucks based on proportion of VMT per class. Title fees, operator licenses and inquiry fees are attributed in proportion to the number of Arizona-based vehicles. All other fees are attributed based on proportion of VMT in Arizona.

Cost Allocation

Costs of construction, maintenance and general operation of highway-related programs are allocated to various vehicle classes and compared with revenues in order to determine whether each class is paying its share of highway-related costs. The method used in cost allocation varies by the type of expenditure. While some costs are common to all vehicles, such as basic (i.e. minimum) pavement requirements and highway patrol, other

[1] It should be noted that the collection of vehicle classification data and the corresponding measurement of VMT are subject to limitations in the frequency and scope of collection. Data collected in Arizona are from samples taken mainly on the State Highway System and are collected for short periods of time and/or infrequent intervals on some highway segments. The data collected are therefore likely to exhibit substantial fluctuation between measurement periods for any given portion of the highway system. While these data are assumed to provide reasonable estimates for statewide aggregates of cost responsibility, the application to smaller subsets of roadways may not be appropriate. Any enhancements that are made to monitor traffic streams will serve to refine and improve the effectiveness and fairness of the model.

costs are allocated to certain vehicle classes in proportion to those vehicles' responsibility for the costs incurred. Extra pavement thickness is required for the operation of heavy trucks on roadways, and thus, these vehicles are allocated additional cost responsibility to account for the additional thickness. The primary factors for allocation of different types of expenditures are shown below.

Table 1: Allocation Factors

Type of Expenditure	Primary Allocation Factor
Construction	
Pavement	
Basic	VMT
Extra thickness	Axle load
Bridges	
Basic	VMT
Extra strength	Gross weight
Other	VMT
Maintenance	
Pavement	Axle load
Other	VMT
Other State Programs	VMT

Costs are allocated among vehicle classes using the Federal Method of allocation. The Federal method assumes a minimum pavement thickness in allocation of pavement construction costs. This minimum is distributed among all vehicle classes, while the cost of thicker pavement is attributed to heavier vehicles in proportion to axle loads. Pavement rehabilitation is also allocated in varying degrees, depending on a vehicle's "consumption" of pavement (i.e. contribution to the need for pavement repair).

Table 2: Allocation Methods

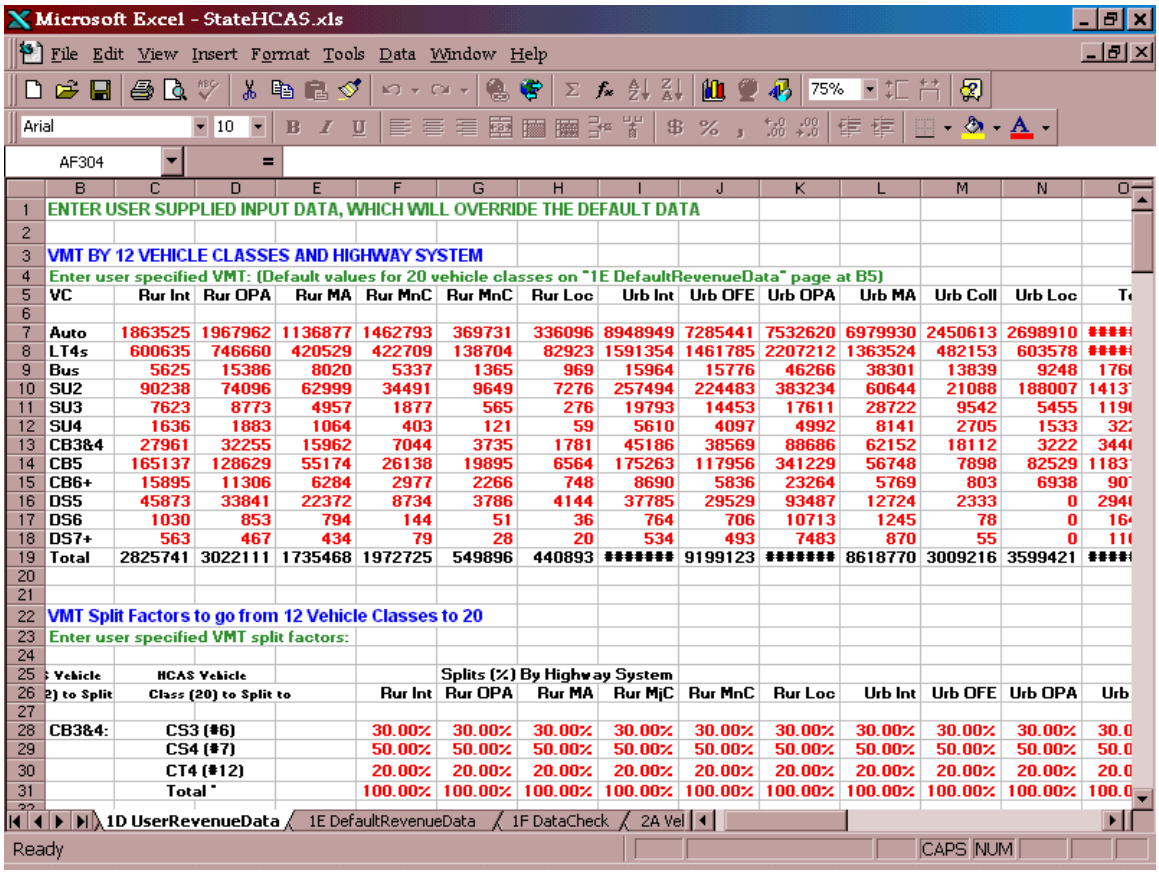
Cost Category	Allocation Method
New Pavement	Minimum pavement thickness
Pavement Rehabilitation	Pavement consumption
New Bridges	Incremental analysis of strength
Bridge Replacement	Incremental analysis of strength / Load bearing function
Bridge Repair	Common cost
Grading for New Facilities	Incremental analysis of earthwork requirements
Engineering	Prorated based on other capital outlays for construction
Right-of-Way	Common cost

III. Comparison of ADOT and "Federal" HCAS Models

A new Federal Model for State Highway Cost Allocation is currently under development. This model provides an alternative for future cost allocation updates prepared by ADOT. One component of this study has been to compare the new Federal Model to the Highway Cost Allocation model currently employed by ADOT.

The new Federal Model is attractive in that its user interface has been simplified considerably from the ADOT HCAS model. Whereas the ADOT model must perform a series of file conversions prior to the actual allocation, the new Federal Model has integrated all of these functions into one spreadsheet. External FORTRAN programs have been replaced with Visual Basic routines embedded in the spreadsheet of the Federal Model. The entire Federal Model consists of two files: the State HCAS spreadsheet, which contains all user input and the allocation programs, and Load Equivalency spreadsheet from which the allocation programs extract weight-related data. As an illustration of this approach, updates to VMT in both models are discussed in greater detail.

Figure 1: New Federal Model HCAS Spreadsheet



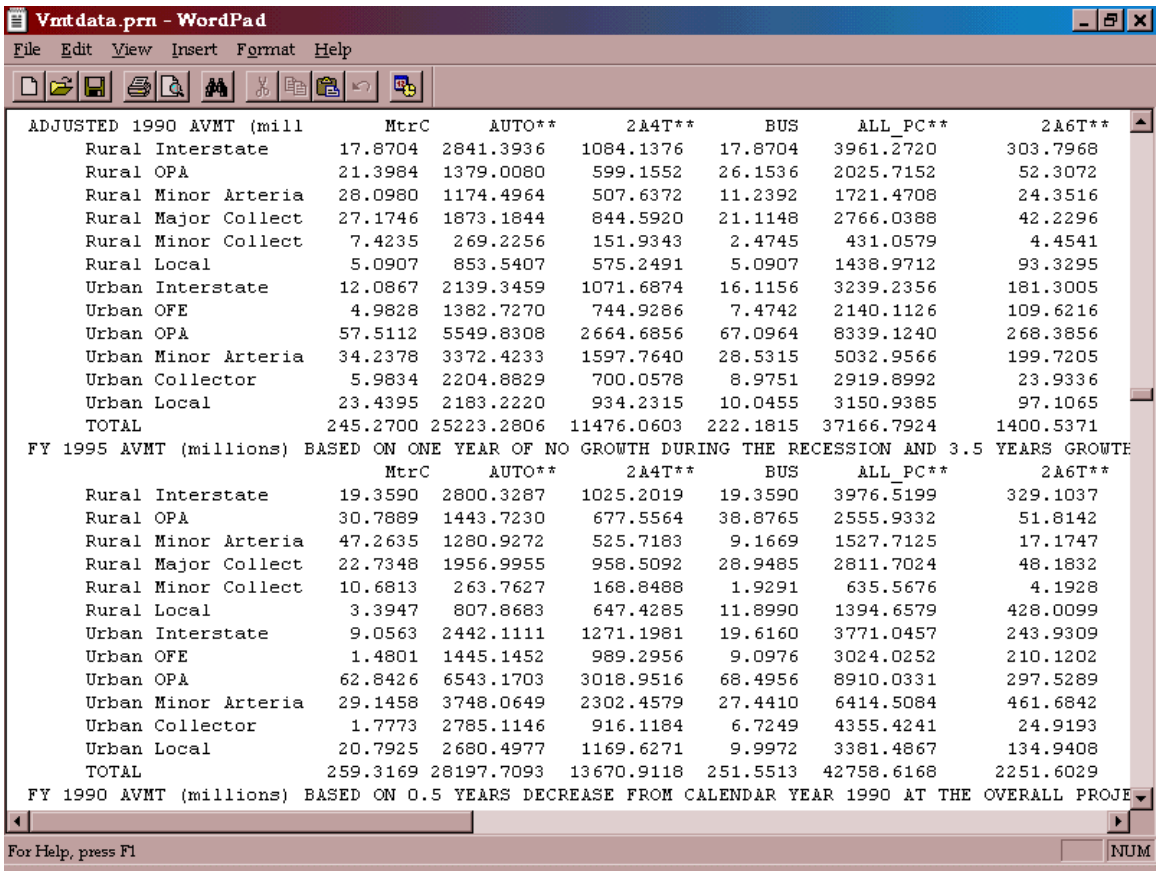
The graphic above illustrates the single-step update process of the Federal Model. VMT data for any period can be entered in the matrix shown below, and variable forecast rates

and periods can be specified in the spreadsheet. Any user-specified growth rate may be used for the cost allocation and the data are all contained within a single file. A series of instructions provided in the spreadsheet shows users how to perform updates using default or user-specified data for a wide range of variables.

Updates to VMT in the ADOT HCAS model require a series of steps. First, a spreadsheet is updated with the new VMT data, similar to the method above. However, because the Fortran program employed in the ADOT model can not read directly from a spreadsheet program, the recalculated data must next be converted to a "print file" (i.e. delimited text format), shown in the graphic below. Changes to values in the print files can not be recaculated in the print file, and must therefore be changed in the associated spreadsheet (which must then be reformatted) or recalculated manually and input using the same number of spaces as the original figures.

This poses a number of problems when updating the ADOT HCAS model. First, as the graphic indicates, program years 1990 and 1995 are "hardwired" into the ADOT model. A successful update requires substitution of data for specific years in different parts of the model to ensure that the corresponding spreadsheet formulas remain accurate. For example, the original update was performed during a recessionary period and assumed a year of stagnant growth in VMT. In order to avoid this assumption in future updates, VMT from a later period must be used in forecasting. Inconsistencies in data requirements are endemic in the ADOT HCAS model because users are not always permitted to specify growth rates or change forecast formulas.

Figure 2: ADOT HCAS Model VMT



Vmtdata.prn - WordPad

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ADJUSTED 1990 AVMT (mill

	MtrC	AUTO**	2A4T**	BUS	ALL_PC**	2A6T**
Rural Interstate	17.8704	2841.3936	1084.1376	17.8704	3961.2720	303.7968
Rural OPA	21.3984	1379.0080	599.1552	26.1536	2025.7152	52.3072
Rural Minor Arteria	28.0980	1174.4964	507.6372	11.2392	1721.4708	24.3516
Rural Major Collect	27.1746	1873.1844	844.5920	21.1148	2766.0388	42.2296
Rural Minor Collect	7.4235	269.2256	151.9343	2.4745	431.0579	4.4541
Rural Local	5.0907	853.5407	575.2491	5.0907	1438.9712	93.3295
Urban Interstate	12.0867	2139.3459	1071.6874	16.1156	3239.2356	181.3005
Urban OFE	4.9828	1382.7270	744.9286	7.4742	2140.1126	109.6216
Urban OPA	57.5112	5549.8308	2664.6856	67.0964	8339.1240	268.3856
Urban Minor Arteria	34.2378	3372.4233	1597.7640	28.5315	5032.9566	199.7205
Urban Collector	5.9834	2204.8829	700.0578	8.9751	2919.8992	23.9336
Urban Local	23.4395	2183.2220	934.2315	10.0455	3150.9385	97.1065
TOTAL	245.2700	25223.2806	11476.0603	222.1815	37166.7924	1400.5371

FY 1995 AVMT (millions) BASED ON ONE YEAR OF NO GROWTH DURING THE RECESSION AND 3.5 YEARS GROWTH

	MtrC	AUTO**	2A4T**	BUS	ALL_PC**	2A6T**
Rural Interstate	19.3590	2800.3287	1025.2019	19.3590	3976.5199	329.1037
Rural OPA	30.7889	1443.7230	677.5564	38.8765	2555.9332	51.8142
Rural Minor Arteria	47.2635	1280.9272	525.7183	9.1669	1527.7125	17.1747
Rural Major Collect	22.7348	1956.9955	958.5092	28.9485	2811.7024	48.1832
Rural Minor Collect	10.6813	263.7627	168.8488	1.9291	635.5676	4.1928
Rural Local	3.3947	807.8683	647.4285	11.8990	1394.6579	428.0099
Urban Interstate	9.0563	2442.1111	1271.1981	19.6160	3771.0457	243.9309
Urban OFE	1.4801	1445.1452	989.2956	9.0976	3024.0252	210.1202
Urban OPA	62.8426	6543.1703	3018.9516	68.4956	8910.0331	297.5289
Urban Minor Arteria	29.1458	3748.0649	2302.4579	27.4410	6414.5084	461.6842
Urban Collector	1.7773	2785.1146	916.1184	6.7249	4355.4241	24.9193
Urban Local	20.7925	2680.4977	1169.6271	9.9972	3381.4867	134.9408
TOTAL	259.3169	28197.7093	13670.9118	251.5513	42758.6168	2251.6029

FY 1990 AVMT (millions) BASED ON 0.5 YEARS DECREASE FROM CALENDAR YEAR 1990 AT THE OVERALL PROJE

For Help, press F1 NUM

The multiple steps required for updating VMT in the ADOT model are similar for other inputs, including vehicle characteristics (e.g. gas mileage and values), tax rates and fees, and obligation program expenditures. This requirement becomes particularly time consuming due to the fact that some of the original spreadsheets were not packaged with the model. Because specific cell dimensions are required for the Fortran programs to work properly, new spreadsheets created for this update could not simply be converted to print files. Formulas were estimated based on documentation provided with the ADOT HCAS model and were entered into new spreadsheets. The output was then printed and re-keyed into the print files by hand. This procedure was required for updating the VMT file shown above, as well as for the vehicle characteristics, and tax rate and fee files.

While the Federal Model generates outputs that reside in the same spreadsheet used for inputs, the ADOT model requires additional print files to which the Fortran allocation programs write ouptuts. Outputs must then be converted from text to spreadsheet format if any additional analyses are to be performed. In total, the ADOT HCAS model consists of 141 separate files, not including the missing spreadsheets mentioned above.

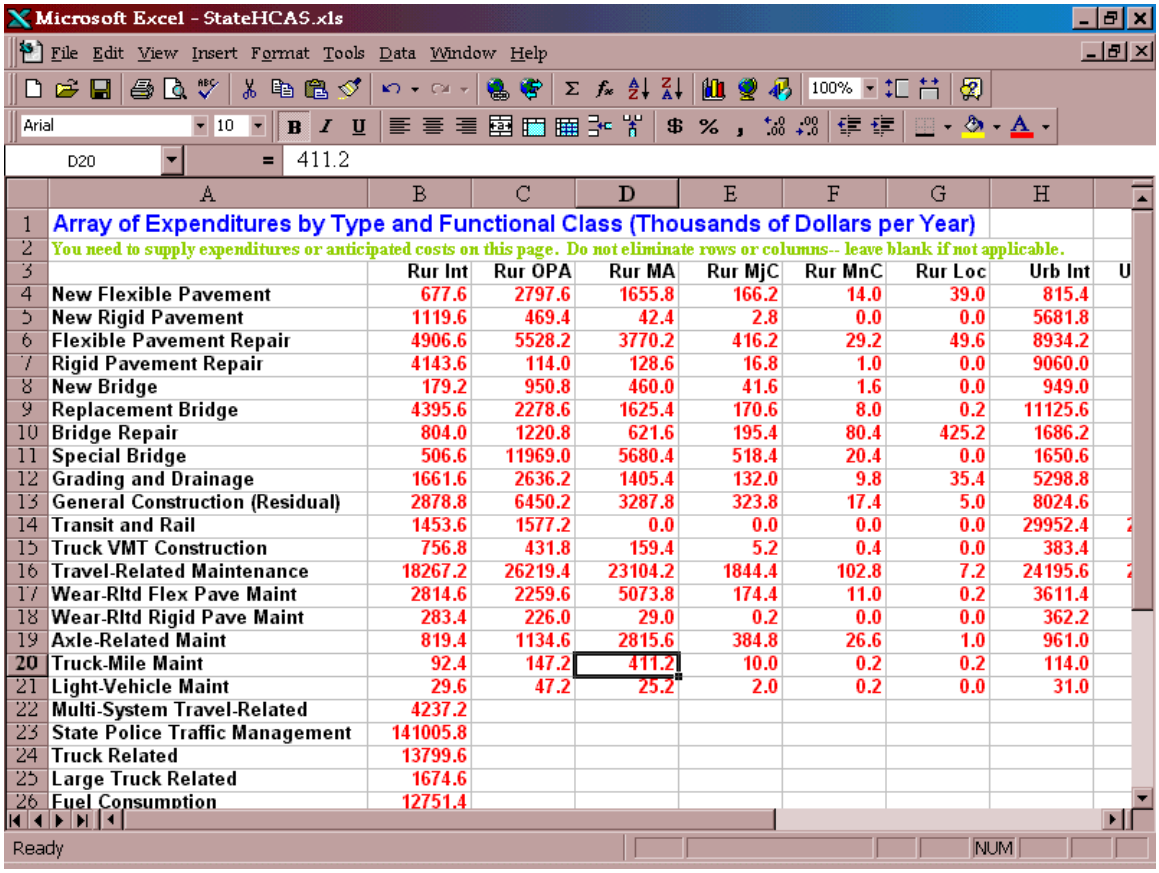
Limitations of the Federal Model

While the new federal cost allocation model would be a much simpler tool for future updates, it is important to note that there are also a number of serious limitations inherent in the test version received by ADOT.

One difficulty with the Federal Model as tested is that the model is not complete. Local revenue input functions and the allocation of costs for different levels of government are not available options in the version provided to ADOT. While this does not suggest that the Federal Model is flawed, it does mean that outputs of the version provided for this study can not be compared to the results of the ADOT HCAS model allocation. The first iteration of the ADOT model was run without changes to local expenditures. In subsequent runs, changes to local expenditures played a significant part in the assessment of cost responsibility. Because the available version Federal Model does not incorporate local-level data, it would only be possible to compare partial allocations based solely on state-level expenditures. Furthermore, as the level-of-government tables are not available in the current version of the Federal Model, the state-level projections could be adversely affected by revenue or cost attributions internal to the model.

Perhaps the greatest impediments to the use of the federal model for Arizona cost allocation studies are the differences in expenditure classifications that exist between ADOT Obligation Programs and the inputs required for the federal model. The new model requires a breakdown of construction expenditures among different categories than those reported by ADOT. Furthermore, as shown below, the new model requires that expenditures be allocated among various functional classes of roadway – an added step that is not reflected in ADOT's obligation program. In order to achieve reliable results, conversion and reallocation of existing construction data would have to be done prior to using the new model.

Figure 3: New Federal Model Expenditures by Type



Microsoft Excel - StateHCAS.xls

File Edit View Insert Format Tools Data Window Help

Arial 10 B I U

D20 = 411.2

	A	B	C	D	E	F	G	H
1	Array of Expenditures by Type and Functional Class (Thousands of Dollars per Year)							
2	You need to supply expenditures or anticipated costs on this page. Do not eliminate rows or columns-- leave blank if not applicable.							
3		Rur Int	Rur OPA	Rur MA	Rur MjC	Rur MnC	Rur Loc	Urb Int
4	New Flexible Pavement	677.6	2797.6	1655.8	166.2	14.0	39.0	815.4
5	New Rigid Pavement	1119.6	469.4	42.4	2.8	0.0	0.0	5681.8
6	Flexible Pavement Repair	4906.6	5528.2	3770.2	416.2	29.2	49.6	8934.2
7	Rigid Pavement Repair	4143.6	114.0	128.6	16.8	1.0	0.0	9060.0
8	New Bridge	179.2	950.8	460.0	41.6	1.6	0.0	949.0
9	Replacement Bridge	4395.6	2278.6	1625.4	170.6	8.0	0.2	11125.6
10	Bridge Repair	804.0	1220.8	621.6	195.4	80.4	425.2	1686.2
11	Special Bridge	506.6	11969.0	5680.4	518.4	20.4	0.0	1650.6
12	Grading and Drainage	1661.6	2636.2	1405.4	132.0	9.8	35.4	5298.8
13	General Construction (Residual)	2878.8	6450.2	3287.8	323.8	17.4	5.0	8024.6
14	Transit and Rail	1453.6	1577.2	0.0	0.0	0.0	0.0	29952.4
15	Truck VMT Construction	756.8	431.8	159.4	5.2	0.4	0.0	383.4
16	Travel-Related Maintenance	18267.2	26219.4	23104.2	1844.4	102.8	7.2	24195.6
17	Wear-Rltd Flex Pave Maint	2814.6	2259.6	5073.8	174.4	11.0	0.2	3611.4
18	Wear-Rltd Rigid Pave Maint	283.4	226.0	29.0	0.2	0.0	0.0	362.2
19	Axle-Related Maint	819.4	1134.6	2815.6	384.8	26.6	1.0	961.0
20	Truck-Mile Maint	92.4	147.2	411.2	10.0	0.2	0.2	114.0
21	Light-Vehicle Maint	29.6	47.2	25.2	2.0	0.2	0.0	31.0
22	Multi-System Travel-Related	4237.2						
23	State Police Traffic Management	141005.8						
24	Truck Related	13799.6						
25	Large Truck Related	1674.6						
26	Fuel Consumption	12751.4						

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In short, the Federal Model can not be used as currently available. An updated version that includes input and allocation options for local government expenditures would yield results that could be directly compared to the ADOT model in terms of methodology. As a preliminary step in creating a simpler means of cost allocation (see page 23), a query was created to sort ADOT's Obligation Program by functional class of roadway. This query can also be used for allocating program expenditures in the Federal Model. However, a means of allocating ADOT's obligation program among the new classes of project expenditures in the Federal Model has not been developed. Because the version of the Federal Model received does not include details or descriptions of the expenditure categories utilized, allocation of the ADOT Obligation Program to these expenditure classes would be arbitrary.

IV. ADOT Highway Cost Allocation Model Results

The results shown in the following tables were forecast using the ADOT HCAS model assuming the "broad case" of highway cost allocation, which includes highway user revenues and expenditures for all levels of government. Revenue control totals for fiscal years 1999 to 2003 were used for allocation among the various vehicle classes and types of expenditures.

The results of this study indicate that, for the forecast period FY 1999-2003, lighter vehicle classes are projected to pay taxes and fees that exceed their cost responsibility, while revenues generated by heavier vehicles are not sufficient to meet these vehicles' cost responsibility. User revenues have grown more rapidly than in previous periods, particularly in the case of autos and single-unit trucks. In the case of pick-ups/SUVs, a vehicle class that has consistently overpaid since the 1993-1997 program period, overpayment has grown with each subsequent update. This persistent overpayment is more attributable to lower cost responsibility than to the change in revenues for the current forecast period.

The revenue to cost responsibility ratios of heavier vehicles have shown a trend toward convergence in prior forecast periods, and that trend is expected to continue in the latest forecast. However, changes in the fee structure for commercial vehicles have reversed the overpayment projected for combination trucks in previous periods. Combination trucks were expected to pay 110 percent of their cost responsibility in the 1996 to 2000 forecast period, but are now projected to *under*pay their cost responsibility by 7 percent. The equity ratio for single unit trucks has remained constant from the previous forecast, at 90 percent revenues to cost responsibility, but shows an equity improvement (i.e. reduction of underpayment) from the 1993 to 1997 forecast.

Rising revenue to cost responsibility ratios for autos and pick-ups/SUVs in the forecast period are primarily attributable to growth in user revenue that exceeds the growth in construction and maintenance costs allocated to these vehicles. Overall, it appears that overpayment by lighter vehicles will subsidize underpayment by buses and heavy trucks to an extent that aggregate revenues are projected to exceed aggregate cost responsibility by 20 percent for the 1999-2003 forecast period.

Aggregate results for the longer FY 1988-2003 period indicate that most vehicle classes will still have failed to pay their full cost responsibility, though the underpayment gap has improved from prior forecasts. Autos will have paid an amount equal to 97 percent of their cost responsibility from 1988 to 2003, and pick-ups/SUVs will have overpaid. The results for heavier vehicle classes indicate that a gap between revenues and cost responsibility remains, and that projected revenue shortfalls from this latest update demonstrate a likely persistence of underpayment by heavier vehicles attributable in part to changes in the fee structure. Results by vehicle class and weight class are shown in greater detail in the sections below.

Revenue, Cost and Equity Ratios by Vehicle Class

The tables below show the annual average figures on revenue, cost and equity ratios by vehicle class for five five-year periods. The five-year period spanning fiscal years 1999 to 2003 indicates that the recent changes to Arizona tax rates have resulted combination trucks paying a significantly lower proportion of cost responsibility than in prior periods. Lighter vehicles pay more, with autos and pick-ups/SUVs paying 130 percent and 174 percent of their respective cost responsibility. In the aggregate, highway users are projected to pay about 20 percent more than their cost responsibility for fiscal years 1999 to 2003.

Although this indicates that some highway users are paying more in taxes than their share of highway spending for building and maintaining roads, it should be noted that in the 1988-1992 and 1993-1997 periods, most users were estimated to be paying substantially less than an equitable share. As shown in the last table of this section, the estimated cumulative totals for fiscal years 1988 to 2003 indicate that in the aggregate, highway users will still have paid slightly less than their full share of cost responsibility. Over the cumulative period, only pick-ups/SUVs are expected to pay their full cost responsibility, while revenues generated by automobile users will account for 97 percent of the cost responsibility for that vehicle class. Despite increasing revenue to cost responsibility ratios in most prior program periods, buses and commercial vehicles, particularly single-unit trucks, are all expected to have underpaid their share of cumulative cost responsibility by at least 11 percent over the fiscal 1988 to 2003 period.

While the revenue to cost responsibility ratios appear quite inequitable for autos and pick-ups/SUVs in the latest forecast period, several points should be kept in mind. Much of the disparity in the current forecast is likely a function of the current forecast of ADOT construction obligations. Obligations for major spot projects and corridor improvements, which are largely allocated to these vehicle classes, are currently projected to decline by more than 50% from 1999 to 2001. Total costs allocated among vehicles have thus grown more slowly than revenues as construction has slowed from its peak in prior forecast periods. However, it seems unlikely that this trend will continue indefinitely, and the current estimates of inequity should also be weighed against the likelihood of greater future cost responsibility on the part of these vehicle classes.

Table 3: Annual Average for Fiscal Years 1999-2003

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$1,021.6	$787.9	130%
Pick-ups/SUVs	$452.9	$260.0	174%
Buses	$9.9	$11.0	90%
Single Unit Trucks	$182.0	$202.1	90%
Combination Trucks	$524.0	$563.4	93%
Totals	$2,190.4	$1,824.3	120%

Table 4: Annual Average for Fiscal Years 1996-2000

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$755.9	$669.7	113%
Pick-ups/SUVs	$441.9	$317.8	139%
Buses	$8.0	$10.0	80%
Single Unit Trucks	$74.0	$82.1	90%
Combination Trucks	$404.6	$366.2	110%
Totals	$1,684.4	$1,445.8	117%

Table 5: Annual Average for Fiscal Years 1995-1999

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$610.7	$669.1	91%
Pick-ups/SUVs	$367.6	$316.5	116%
Buses	$6.9	$10.1	68%
Single Unit Trucks	$64.1	$82.3	78%
Combination Trucks	$398.6	$362.8	110%
Totals	$1,447.9	$1,440.8	100%

Table 6: Annual Average for Fiscal Years 1993-1997

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$564.8	$668.4	85%
Pick-ups/SUVs	$335.2	$313.7	107%
Buses	$5.6	$9.9	57%
Single Unit Trucks	$57.1	$81.6	70%
Combination Trucks	$365.7	$356.5	103%
Totals	$1,328.4	$1,430.1	93%

Table 7: Annual Average for Fiscal Years 1988-1992

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$441.4	$737.7	60%
Pick-ups/SUVs	$264.1	$326.4	81%
Buses	$4.3	$10.7	40%
Single Unit Trucks	$44.7	$93.0	48%
Combination Trucks	$294.3	$444.5	66%
Totals	$1,048.8	$1,612.3	65%

Table 8: Cumulative Totals for Fiscal Years 1988-2003

(Dollars in Millions)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$11,323.2	$11,643.0	97%
Pick-ups/SUVs	$5,948.9	$4,829.1	123%
Buses	$113.2	$168.2	67%
Single Unit Trucks	$1,533.6	$1,967.5	78%
Combination Trucks	$6,435.1	$7,213.8	89%
Totals	$25,354.0	$25,821.5	98%

Table 9: Cost Responsibility Ratios by Five-Year Fiscal Period

Vehicle Class	1988-1992	1993-1997	1995-1999	1996-2000	1999-2003
Autos	60%	85%	91%	113%	130%
Pick-ups/SUVs	81%	107%	116%	139%	174%
Buses	40%	57%	68%	80%	90%
Single Unit Trucks	48%	70%	78%	90%	90%
Combination Trucks	66%	103%	110%	110%	93%
Totals	65%	93%	100%	117%	120%

Revenue, Cost and Equity Ratios by Weight Class

The following tables illustrate average annual user revenues, cost responsibility and equity ratios for the same program periods by vehicle weight class. Particularly notable is the degree to which the lightest-weight vehicles pay a disproportionate share of user revenues in the latest forecast period. Vehicles weighing 8,000 lb. or less are forecast to pay 141 percent of their cost responsibility in fiscal 1999 to 2003. This group comprises the weight class with the highest level of overpayment for the current forecast period, with a revenue allocation that has grown far more quickly than its share of cost responsibility.

Most heavier weight categories are projected to pay their fair share of cost responsibility or slightly more in the 1999 to 2003 forecast period, but in general overpayment by these vehicles has declined from the prior forecast period. The change in projected revenue to cost responsibility ratios for *all* heavier vehicles observed between this update and the previous update suggests that recent changes in the tax and fees structure have reduced the relative burden on heavier vehicles to the extent that most will fail to pay their share of cost responsibility over the aggregated 1988 to 2003 period. Exceptions to this observation are vehicles registered between 36,000 and 75,000 lb., which are expected to collectively overpay in the aggregate period by 5.8 percent.

The lightest vehicle class, consisting primarily of passenger automobiles, continues to generate the majority of user revenues. Revenues for this weight class are forecast to grow more quickly than in previous program periods. Migration-driven growth in the driver-age population, the popularity of less fuel-efficient "sport utility" vehicles, and inflation of vehicle prices may all play a role in the revenue increase in the latest program period. While the cumulative 1988 to 2003 forecast by vehicle type (see p. 13) indicates that autos will achieve a revenue to cost responsibility ratio of 97 percent by the end of the 1999 to 2003 forecast period, the same analysis by weight class results in 105 percent for lighter vehicles. In the aggregate, underpayment persists for most weight classes, particularly the mid-range weight classes (8,000 to 36,000 lb.) and the heaviest vehicles. Cost responsibility has increased for all weight classes in the latest forecast, but revenues are projected to grow more rapidly in nearly every case as highway users continue to pay for capital projects begun in previous program periods.

Table 10: Annual Average for Fiscal Years 1999-2003
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$1,474.1	$1,047.6	141%
8,000-10,000 lb.	$39.8	$40.2	99%
10,000-12,000 lb.	$14.4	$14.2	101%
12,000-14,000 lb.	$4.3	$3.6	118%
14,000-16,000 lb.	$7.9	$7.7	102%
16,000-18,000 lb.	$6.4	$5.9	108%
18,000-20,000 lb.	$11.5	$10.6	109%
20,000-22,000 lb.	$4.0	$3.6	110%
22,000-24,000 lb.	$6.6	$6.5	101%
24,000-26,000 lb.	$21.2	$20.7	102%
26,000-28,000 lb.	$5.3	$5.7	93%
28,000-30,000 lb.	$5.5	$7.5	74%
30,000-32,000 lb.	$4.1	$5.3	78%
32,000-36,000 lb.	$9.4	$11.1	85%
36,000-40,000 lb.	$8.8	$8.0	110%
40,000-45,000 lb.	$6.0	$5.4	112%
45,000-50,000 lb.	$18.6	$19.9	94%
50,000-55,000 lb.	$29.0	$29.2	99%
55,000-60,000 lb.	$11.5	$10.2	112%
60,000-65,000 lb.	$13.2	$10.9	121%
65,000-70,000 lb.	$9.4	$7.1	132%
70,000-75,000 lb.	$18.4	$15.3	120%
75,000-80,000 lb.	$461.0	$528.1	87%
Total	$2,190.4	$1,824.3	120%

Table 11: Annual Average for Fiscal Years 1996-2000
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$1,197.3	$987.2	121%
8,000-10,000 lb.	$12.3	$17.0	72%
10,000-12,000 lb.	$4.9	$6.4	77%
12,000-14,000 lb.	$1.9	$1.9	100%
14,000-16,000 lb.	$3.0	$3.5	86%
16,000-18,000 lb.	$2.6	$2.8	93%
18,000-20,000 lb.	$4.6	$4.7	98%
20,000-22,000 lb.	$1.8	$1.8	100%
22,000-24,000 lb.	$2.9	$3.2	91%
24,000-26,000 lb.	$9.2	$9.6	96%
26,000-28,000 lb.	$2.8	$3.1	90%
28,000-30,000 lb.	$2.9	$3.7	78%
30,000-32,000 lb.	$2.1	$2.5	84%
32,000-36,000 lb.	$5.5	$5.5	100%
36,000-40,000 lb.	$5.8	$4.4	132%
40,000-45,000 lb.	$3.6	$2.6	138%
45,000-50,000 lb.	$11.7	$10.1	116%
50,000-55,000 lb.	$17.1	$12.6	136%
55,000-60,000 lb.	$7.4	$5.3	140%
60,000-65,000 lb.	$8.6	$5.3	162%
65,000-70,000 lb.	$6.4	$4.1	156%
70,000-75,000 lb.	$12.3	$8.2	150%
75,000-80,000 lb.	$357.7	$340.4	105%
Total	$1,684.4	$1,445.9	116%

Table 12: Annual Average for Fiscal Years 1995-1999
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$978.0	$985.4	99%
8,000-10,000 lb.	$10.5	$17.2	61%
10,000-12,000 lb.	$4.2	$6.5	65%
12,000-14,000 lb.	$1.6	$1.9	84%
14,000-16,000 lb.	$2.6	$3.6	72%
16,000-18,000 lb.	$2.2	$2.8	79%
18,000-20,000 lb.	$3.9	$4.8	81%
20,000-22,000 lb.	$1.6	$1.9	84%
22,000-24,000 lb.	$2.5	$3.2	78%
24,000-26,000 lb.	$7.9	$9.6	82%
26,000-28,000 lb.	$2.5	$3.1	81%
28,000-30,000 lb.	$2.5	$3.7	68%
30,000-32,000 lb.	$1.9	$2.4	79%
32,000-36,000 lb.	$5.0	$5.5	91%
36,000-40,000 lb.	$5.2	$4.4	118%
40,000-45,000 lb.	$3.3	$2.6	127%
45,000-50,000 lb.	$10.7	$10.0	107%
50,000-55,000 lb.	$15.4	$12.6	122%
55,000-60,000 lb.	$6.8	$5.3	128%
60,000-65,000 lb.	$8.0	$5.3	151%
65,000-70,000 lb.	$6.0	$4.0	150%
70,000-75,000 lb.	$11.7	$8.1	144%
75,000-80,000 lb.	$353.8	$337.1	105%
Total	$1,447.8	$1,441.0	100%

Table 13: Annual Average for Fiscal Years 1993-1997
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$899.7	$981.8	92%
8,000-10,000 lb.	$9.5	$17.1	56%
10,000-12,000 lb.	$3.8	$6.4	59%
12,000-14,000 lb.	$1.5	$1.9	79%
14,000-16,000 lb.	$2.3	$3.5	66%
16,000-18,000 lb.	$2.0	$2.8	71%
18,000-20,000 lb.	$3.5	$4.7	74%
20,000-22,000 lb.	$1.4	$1.8	78%
22,000-24,000 lb.	$2.2	$3.1	71%
24,000-26,000 lb.	$6.9	$9.5	73%
26,000-28,000 lb.	$2.1	$3.0	70%
28,000-30,000 lb.	$2.2	$3.6	61%
30,000-32,000 lb.	$1.6	$2.4	67%
32,000-36,000 lb.	$4.3	$5.4	80%
36,000-40,000 lb.	$4.4	$4.4	100%
40,000-45,000 lb.	$2.8	$2.6	108%
45,000-50,000 lb.	$9.2	$9.9	93%
50,000-55,000 lb.	$13.3	$12.4	107%
55,000-60,000 lb.	$5.9	$5.2	113%
60,000-65,000 lb.	$7.1	$5.2	137%
65,000-70,000 lb.	$5.4	$4.0	135%
70,000-75,000 lb.	$10.8	$8.0	135%
75,000-80,000 lb.	$326.6	$331.2	99%
Total	$1,328.5	$1,429.9	93%

Table 14: Annual Average for Fiscal Years 1988-1992
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$705.3	$1,063.8	66%
8,000-10,000 lb.	$7.4	$20.0	37%
10,000-12,000 lb.	$2.9	$7.4	39%
12,000-14,000 lb.	$1.2	$2.1	57%
14,000-16,000 lb.	$1.8	$4.0	45%
16,000-18,000 lb.	$1.6	$3.2	50%
18,000-20,000 lb.	$2.7	$5.5	49%
20,000-22,000 lb.	$1.1	$2.1	52%
22,000-24,000 lb.	$1.7	$3.6	47%
24,000-26,000 lb.	$5.4	$10.8	50%
26,000-28,000 lb.	$1.7	$3.4	50%
28,000-30,000 lb.	$1.7	$4.0	43%
30,000-32,000 lb.	$1.3	$2.7	48%
32,000-36,000 lb.	$3.4	$6.1	56%
36,000-40,000 lb.	$3.6	$5.0	72%
40,000-45,000 lb.	$2.3	$3.0	77%
45,000-50,000 lb.	$7.5	$11.7	64%
50,000-55,000 lb.	$10.7	$14.4	74%
55,000-60,000 lb.	$4.8	$6.1	79%
60,000-65,000 lb.	$5.7	$6.3	90%
65,000-70,000 lb.	$4.3	$4.9	88%
70,000-75,000 lb.	$8.6	$9.7	89%
75,000-80,000 lb.	$262.2	$412.5	64%
Total	$1,048.9	$1,612.3	65%

Table 15: Cumulative for Fiscal Years 1988-2003
(Dollars in Millions)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$17,266.3	$16,467.4	105%
8,000-10,000 lb.	$302.6	$403.6	75%
10,000-12,000 lb.	$112.8	$146.3	77%
12,000-14,000 lb.	$37.7	$40.1	94%
14,000-16,000 lb.	$64.6	$79.5	81%
16,000-18,000 lb.	$53.9	$62.3	86%
18,000-20,000 lb.	$95.9	$108.6	88%
20,000-22,000 lb.	$35.2	$39.5	89%
22,000-24,000 lb.	$57.1	$69.5	82%
24,000-26,000 lb.	$182.4	$215.1	85%
26,000-28,000 lb.	$50.0	$63.8	78%
28,000-30,000 lb.	$51.8	$79.6	65%
30,000-32,000 lb.	$38.5	$54.8	70%
32,000-36,000 lb.	$94.0	$118.6	79%
36,000-40,000 lb.	$93.4	$91.4	102%
40,000-45,000 lb.	$61.4	$57.6	107%
45,000-50,000 lb.	$194.8	$218.0	89%
50,000-55,000 lb.	$291.7	$293.1	100%
55,000-60,000 lb.	$122.3	$113.3	108%
60,000-65,000 lb.	$142.5	$117.6	121%
65,000-70,000 lb.	$104.5	$84.5	124%
70,000-75,000 lb.	$205.1	$173.7	118%
75,000-80,000 lb.	$5,696.0	$6,723.7	85%
Total	$25,354.6	$25,821.6	98%

Table 16: Cost Responsibility Ratios by Five-Year Fiscal Period

Weight Class	1988-1992	1993-1997	1995-1999	1996-2000	1999-2003
0-8,000 lb.	66%	92%	99%	121%	141%
8,000-10,000 lb.	37%	56%	61%	72%	99%
10,000-12,000 lb.	39%	59%	65%	77%	101%
12,000-14,000 lb.	57%	79%	84%	100%	118%
14,000-16,000 lb.	45%	66%	72%	86%	102%
16,000-18,000 lb.	50%	71%	79%	93%	108%
18,000-20,000 lb.	49%	74%	81%	98%	109%
20,000-22,000 lb.	52%	78%	84%	100%	110%
22,000-24,000 lb.	47%	71%	78%	91%	101%
24,000-26,000 lb.	50%	73%	82%	96%	102%
26,000-28,000 lb.	50%	70%	81%	90%	93%
28,000-30,000 lb.	43%	61%	68%	78%	74%
30,000-32,000 lb.	48%	67%	79%	84%	78%
32,000-36,000 lb.	56%	80%	91%	100%	85%
36,000-40,000 lb.	72%	100%	118%	132%	110%
40,000-45,000 lb.	77%	108%	127%	138%	112%
45,000-50,000 lb.	64%	93%	107%	116%	94%
50,000-55,000 lb.	74%	107%	122%	136%	99%
55,000-60,000 lb.	79%	113%	128%	140%	112%
60,000-65,000 lb.	90%	137%	151%	162%	121%
65,000-70,000 lb.	88%	135%	150%	156%	132%
70,000-75,000 lb.	89%	135%	144%	150%	120%
75,000-80,000 lb.	64%	99%	105%	105%	87%
Total	65%	93%	100%	116%	120%

Limitations of These Results

An evaluation of the cost allocation results generated with the ADOT model should take the following limitations into account:

1. The ADOT HCAS model allocates motor carrier fees based upon tax rates that were in effect when the model was created. The AZREVIN print file requires the entry of a tax *rate* in order for the allocation of motor carrier fees to take effect. Because the current tax structure imposes a flat fee rather than a rate per mile of travel, the HCAS model does not provide an adequate allocation of this fee. For the purpose of this update, motor carrier fees were assigned to "Other Truck VMT" in the revenue control totals. While an allocation of motor carrier fees with registration fees would be superior in that motor carrier fees could be assigned using the weight-adjusted scale employed for registration fees, this method would result in a small portion of the motor carrier fees being assigned to non-commercial vehicles. It is recognized that assignment of motor carrier fees by truck VMT is an imperfect measure, but is considered preferable to misallocation among non-commercial vehicles for the scope of this study.

2. The format of data reporting was changed for the latest ADOT Five-Year Construction Program. This caused considerable difficulty in the assignment of costs to the old expenditure categories. A rough estimate method was used to allocate these expenditures, and errors in classification could potentially have a substantial impact on the overall cost allocation process. (see Appendix A for further discussion).

These difficulties and the inherent complexities of working with the ADOT model prompted an effort to allocate costs among vehicle classes using an alternate, more simplified methodology. A simplified allocation process developed for this study and results of that process are discussed in the following section.

V. Simplified Methodology for Cost and Revenue Allocation

An important goal of this study was the assessment of the Arizona HCAS model and the new "Federal" State HCAS model to determine the usability of each. Cost allocation can be a useful tool for analysis of the equity of taxes and fees imposed on users of the highway system. However, the benefits of allocation must also be weighed against the cost of completing studies on a regular basis. Because the process can be a time-consuming endeavor, regular updates are more likely to occur when the process is simplified. Both the ADOT HCAS model and the new Federal Model have significant drawbacks in terms of portability, user-friendliness, completeness and/or simplicity. For this reason, an attempt has been made to approximate the allocation of cost responsibility and revenues to different vehicle classes in a much simpler manner.

Simplified Method of Cost Allocation by Vehicle Class

A simplified method for approximating cost responsibility was suggested by John Semmens as part of this analysis. The assumption to be tested was that system-wide expenditures could be reasonably attributed to vehicle classes based on two basic scenarios. In the interest of simplicity, the only criteria for allocation of construction expenditures was whether the expenditure occurred for an urban or a rural highway segment. Urban segment expenditures were allocated based on the proportion of urban VMT attributable to a given vehicle class, which assumes that urban expenditures are primarily driven by the need for increased capacity on the highway system. This scenario had the highest impact on automobiles, which comprise the bulk of travel on all functional classes of roadway.

In contrast, rural expenditures were assumed to be largely attributable to variables such as flexible pavement repair, climbing lanes and the like. It was therefore assumed that heavy-vehicle traffic had the greatest impact on rural expenditures. For this reason, cost responsibility for construction and maintenance on rural system segments was attributed based on VMT weighted by equivalent single axle loads (ESALs). ESAL ratios assign a far higher proportion of cost responsibility to heavier vehicle classes, which offset these vehicles' lower VMT. Further detail of the ESALs assigned to different vehicle types is provided below.

Common costs such as signage and highway patrol expenses were also assigned based on VMT, *regardless* of highway segment classification. It was expected that these expenditures would have the most direct relationship to the amount of travel on a given roadway, and not to the type or weight of vehicles traveling a particular route. Again, this meant automobiles and pick-ups/SUVs would bear the largest share of these expenses. The table below indicates the manner of attribution used for different construction and maintenance expenditures.

Table 17: Simplified Model Allocation Methods			
Expenditure	**Segment Type**	**Allocation Method**	**Primary Responsibility by Vehicle Class**
Construction and Maintenance	Rural	Weight (ESALs)	Single-Unit and Combination Trucks
	Urban	VMT	Autos and Pick-ups
Common	Rural and Urban	VMT	Autos and Pick-ups

To attribute shares of traffic among vehicle classes, forecast VMT were aggregated by basic vehicle class and assigned to rural or urban categories.[2] As shown below, automobiles and pick-ups account for the majority of travel on both rural and urban systems. These vehicles can therefore be expected to receive the bulk of cost responsibility for urban and common expenditures, which were attributed based on VMT. However, while autos and pick-ups also account for most of the VMT measured on rural segments, the share of rural expenditures attributed to these vehicle classes was greatly offset by their relatively small ESAL coefficients. Combination trucks were more highly represented on rural system segments than on urban segments, in contrast with most other vehicle types. The combination of higher ESAL factors and a proportionally greater share of rural VMT suggests combination trucks will bear the highest cost responsibility for construction and maintenance of the rural system.

Table 18: Fiscal Year 2001 AVMT (Millions)

Vehicle Type	**Rural**		**Urban**		**Total**	
	Count	**%**	**Count**	**%**	**Count**	**%**
Autos	8,687.8	48.3	19,769.2	53.5	28,457.0	51.8
Pick-ups	4,003.3	22.3	9,667.6	26.2	13,670.9	24.9
Buses	110.2	0.6	141.4	0.4	251.6	0.5
Single-Unit Trucks	1,123.3	6.2	2,249.7	6.1	3,373.0	6.1
Combination Trucks	4,051.8	22.5	5,119.4	13.9	9,171.2	16.7
Total	17,976.4	100.0	36,947.3	100.0	54,923.7	100.0

ESAL coefficients used in allocating rural expenditures were calculated using a base axle load of 18,000 pounds. Deviations from this base weight are magnified by a fourth-power exponential relationship between axle load and potential pavement damage. For example, the front-axle load for a typical single-unit, three-axle truck is 16,000 lb., which equates to an ESAL of 0.62 (i.e. $(16{,}000/18{,}000)^4$). ESALs for each axle are summed for each vehicle type to arrive at a final coefficient. These were assigned to vehicle classes based on a standard vehicle configuration report prepared by FHWA.[3] A more complicated assessment of variable ESAL coefficients for different vehicle configurations was also created in order to allocate costs among vehicles by weight class. Standardized ESAL coefficients used for the allocation by vehicle class are shown in the following table.

[2] Projections were made using the same methodology employed in the ADOT HCAS update.
[3] *Comprehensive Truck Size and Weight Study*, FHWA, 1995

Table 19: ESAL Estimates					
Vehicle Type	**Weight Estimate (000)**	**ESAL Estimates**			
		Axle 1	**Axle 2[1]**	**Axle 3[1]**	**TOTAL**
Auto	3.0	0.0001	0.0000		0.0001
Pick-up	4.5	0.0009	0.0000		0.0010
Bus	30.0	0.0953	0.1306		0.2258
Single-Unit Truck	48.0	0.6243	0.8600		1.4843
Combination Truck	80.0	0.1975	1.0900	1.0900	2.3775

Notes: 1. Axle 2 and 3 are axle pairs in the case of buses and trucks.
Source: *Comprehensive Truck Size and Weight Study*, FHWA, 1995

Attribution of Expenditure Data

Expenditure data were compiled in three categories: Construction Program expenditures, Local Government expenditures, and Common Costs such as ADOT's overhead and operating expenses. Expenditure data from each category were allocated to Rural and Urban/Common categories based on different methods, depending on the manner in which the source data were presented. The allocation methods for each category and data source were as follows:

Construction Program Expenditures

Data sources used to estimate construction program expenditures include ADOT's Five-Year Obligation Program, the "Available for Construction" portion of ADOT's Discretionary Fund, and Maricopa and Pima County freeway expenditures. Because of the amount of detail provided in the Obligation Program, the split of expenditures derived for this data source was also used to allocate the remainder of the Discretionary Fund construction budget not accounted for by the Obligation Program.

Obligation Program expenditures were the most difficult to sort, due to the fact that most expenditures are assigned to specific road segments. The Obligation Program database was initially sorted by route number to identify common (system-wide) costs. Expenditures coded to "Route 999" were assumed to be common costs, and were therefore allocated to the Urban/Common category. However, once these common expenditures were sorted, a more complicated process of identifying each of the 477 route-specific line items by functional class of roadway was used.

A database of Arizona highway segments by functional class of roadway was imported into Access, along with the 1999-2003 Obligation Program. A query was run on the two sets of data, identifying route number, beginning and ending mile posts, functional class of roadway, and expenditures. The query output created functional classifications for 370 line item expenditures in the Obligation Program based on route and mile post boundaries. The remaining 107 items were classified manually.

In the case of line items with split segments, expenditures were divided among class of roadway based upon the proportional length of each classified segment in the line item. For example, if expenditures in line item 1 cover miles 0 to 10 on Route A, and Route A miles 0 to 7 are classified as "rural" while miles 7 to 10 are classified as "urban," then 70% of line item 1 expenditures would be classified as "rural" and 30% classified as "urban." While it is not likely that system improvements are evenly distributed in this manner for any given project, the assumption was made that rural versus urban distributions would tend to gravitate toward a length-weighted equivalence over the entire state highway system. The results of the query and sort process for the 1999-2003 Obligation Program are shown in the following table.

Table 20: Simplified Model Allocation of Major Costs

Obligation Program, 1999 to 2003	Urban/Common	Rural
Common Costs (Rte 999)	$ 623,985	
Query Results	$ 378,524	$ 605,006
Manual Classification	$ 43,318	$ 307,153
Total	$ 1,045,827	$ 912,159

Excluding common costs such as highway patrol and safety measures, 68.4 percent of construction and maintenance costs were assigned to "rural" segments. Despite the lower attribution of segment-specific costs to "urban" segments, the large common cost category pushed expenditures attributable to VMT higher than weight-based costs for the final analysis. Of all expenditures in the 1999-2003 Obligation Program, 53.4 percent were allocated to vehicle classes based on VMT (i.e. Urban/Common costs) and 46.6 percent were allocated to vehicle classes based on weight (i.e. Rural costs).

The splits of rural, urban and common costs obtained through analysis of the Obligation Program were applied to the remaining balance of the ADOT Discretionary Fund "Available for Construction." This remaining balance included state funds not yet allocated, as well as unassigned federal aid funds for 1999 to 2003. The projection of federally-funded construction projects was factored upward using the ratio by which ISTEA aid in the Discretionary Fund Analysis exceeded the federal portion of the 1999 to 2003 Obligation Program. The total federal allocation was then added to the state portion of the Obligation Program, as well as any remaining state HURF allocations available for construction.

Freeway expenditures in Maricopa County were also factored into the construction program expenditures. However, unlike the balance of state and federally-funded projects derived from the ADOT Discretionary Fund analysis, these regional expenditures were *not* allocated based on the Obligation Program split illustrated above. Because the MAG program specifically supports regional freeways in an urbanized area, these expenditures were assigned to the Urban/Common cost allocation in their entirety.[4]

[4] This method of allocating regional freeway expenditures assumes that capacity requirements, estimated based on peak-period VMT, are the primary impetus for system improvements in urbanized areas.

Local Expenditures

Data were compiled from Section III., "Disbursements for Road and Street Purposes," in the aggregated (i.e. County and Municipality) Survey of Local Expenditures and from the ADOT Distribution Forecast of HURF Revenues. The most recent Survey of Local Expenditures data available were from the July, 1997 survey. Ratios of county and city expenditures to total local expenditures were compiled from the 1997 survey, as were proportional breakdowns of city and county expenditures by type of spending (e.g. maintenance, administration, etc.). These proportions were then applied to the average forecast "State Aid to Local Governments from the HURF" for the 1999 to 2003 Program Period. From 1992 to 1997, local receipts from the state comprised 86.4 percent of total expenditures by local governments. The State Aid forecast was used as a control for local expenditures, which were then factored upward by the inverse of the State Aid ratio to reflect local spending funded by other sources. The expenditure categories assigned to local highway disbursements are shown in the table below.

Table 21: Simplified Model Allocation of Local Government Expenditures

Local Highway Disbursements	Percentage of Total Local Expenditures[1]	Allocation Category
Capital outlays		
Counties	11.3%	ESALs
Cities and Towns	29.1%	VMT
Maintenance		
Pavement	12.3%	ESALs
Non-Pavement	17.0%	VMT
Road and street services (e.g. Traffic control)	9.9%	VMT
General administration/miscellaneous	7.4%	VMT
Highway law enforcement & safety	4.9%	VMT
Interest on Bonds and Notes	8.0%	VMT

Note: 1. Per breakdown in the 1997 ADOT Survey of Local Expenditures

Services and general administration costs were considered to be common costs allocated by VMT. In the case of capital outlays, county-level expenditures were allocated to the Rural category, whereas expenditures by municipalities were allocated to the Urban category. These assignments were made under the assumption that the majority of county capital outlays were made outside of municipal jurisdictions and were therefore made to Rural segments. Maintenance costs were split into pavement and non-pavement maintenance at both the county and municipality levels, based on estimates of statewide maintenance expenditures provided by the ADOT Maintenance Section.[5] Pavement-related maintenance costs were assumed to be the result of pavement wear more appropriately allocated to vehicles based on weight, while non-pavement maintenance costs were allocated as common costs according to VMT.

[5] The average statewide maintenance program for the past two fiscal periods was comprised of approximately 12.3 percent pavement costs and 87.7 percent non-pavement costs.

Common Costs

Common costs allocated to different vehicle classes included ADOT's 1999 to 2003 Operating Program from the Discretionary Fund Analysis and the interest on RARF and HURF bonds. Debt retirement was not included because the principal amount of these debt obligations has already been accounted for by including construction costs funded from bond proceeds. The annual average of state "common costs" for 1999 to 2003 was allocated in its entirety based on VMT, under the assumption that the state operating program and debt service were common costs to be borne based upon frequency of road usage. These costs were thus allocated to vehicles based solely upon raw shares of VMT, with no consideration of weight-based responsibility. Note that the "common costs" included in the Discretionary Fund Operating Program include such expenditures as agency overhead and DPS transfers. These common costs do *not* include common expenditures associated with construction, such as planning and excavation. The latter are allocated as "Route 999" common costs as defined in the Construction Program allocation methodology on pages 24 and 25.

Cost Allocation Results by Vehicle Class

Common costs and urban expenditures were allocated based on the proportion of VMT assigned to each vehicle class. In the table below, the values in the "Proportion of VMT" column represent the share of traffic for each vehicle class on Arizona's urban segments. These values were multiplied by the totals for the estimated 1999-2003 Construction Programs, Local Government expenditures and the Common Costs that were assigned to the Urban/Common expenditure category as discussed above.

Autos bore the highest share of cost responsibility for projected Urban/Common expenditures (53.5 percent), followed by pick-ups (26.2 percent) and combination trucks (13.9 percent). Because Urban/Common expenditures were allocated based solely on share of VMT, the proportion of these expenditures allocated to each vehicle class will match the share of program period VMT attributed to that class. The Discretionary Fund expenditures comprised the majority of total costs, followed by local expenditures and the Obligation Program expenditures. Total Urban/Common expenditures for the average program year were projected at nearly $1.4 billion.

Table 22: Allocation by VMT (Urban Expenditures and Common Costs, 1999 to 2003)
(Dollar values in thousands)

Vehicle Type	Proportion of VMT	Construction Programs	Local Expenditures	Common Costs	Total Allocation
Autos	0.5351	$238,443	$324,454	$170,470	$733,367
Pick-ups	0.2617	$116,605	$158,667	$83,364	$358,636
Buses	0.0038	$1,705	$2,320	$1,219	$5,244
Single-Unit Trucks	0.0609	$27,135	$36,923	$19,400	$83,458
Combination Trucks	0.1386	$61,747	$84,020	$44,144	$189,911
Common Totals	1.0000	$445,635	$606,384	$318,597	$1,370,616

Rural expenditures were assigned based upon an allocation factor that weighted the proportion of VMT for each vehicle class by the ESAL coefficient for a sample vehicle of each class. First, "Proportion of VMT" was multiplied by the ESAL estimate to determine a weighted proportion of expenditures. Each vehicle class's weighted proportion was then divided by the sum of weighted proportions to determine a final "Weighted Allocation Factor." This factor was multiplied by the "rural" values of the Obligation Program and the Survey of Local Expenditures to attribute weight-based costs to vehicle classes.

A comparison of the "Proportion of VMT" and the "Weighted Allocation Factor" columns indicates the extent to which ESALs played a role in the final distribution of weight-based expenditures. Though autos and pick-ups comprise the majority of traffic on rural segments, the effect of ESAL weighting was such that only 0.04 percent of weight-based costs were attributed to these vehicle classes. In contrast, single-unit and combination trucks represented 6.3 percent and 22.5 percent of rural traffic respectively, but were assigned over 99 percent of weight-based cost responsibility.

Table 23: Allocation by ESAL (Rural Expenditures, 1999 to 2003)
(Dollar values in thousands)

	Proportion of VMT	Weighted Allocation Factor	Construction Programs	Local Expenditures	Total Allocation
Autos	0.4833	0.0001	$29	$12	$41
Pick-ups	0.2227	0.0003	$109	$44	$154
Buses	0.0061	0.0022	$702	$285	$986
Single-Unit Trucks	0.0625	0.1471	$47,007	$19,065	$66,072
Combination Trucks	0.2254	0.8502	$271,605	$110,156	$381,761
Rural Totals	1.0000	1.0000	$319,453	$129,561	$449,015

End results for the alternate allocation method developed for this study are shown in the following table. The cost responsibility estimates represent summations of urban/common and rural cost responsibilities estimated above. The overall results are similar to the results obtained with the ADOT HCAS model (see page 11). However, certain disparities exist.

Table 24: Annual Cost Responsibility by Vehicle Class, 1999 to 2003 (Simplified Methodology)

(Dollar values in thousands)

Vehicle Type	Construction Programs	Local Expenditures	Common Costs	Total Responsibility
Autos	$238,473	$324,466	$170,470	$733,409
Pick-ups	$116,714	$158,711	$83,364	$358,789
Buses	$2,407	$2,605	$1,219	$6,230
Single-Unit Trucks	$74,142	$55,988	$19,400	$149,530
Combination Trucks	$333,352	$194,175	$44,144	$571,672
Totals	$765,088	$735,945	$318,597	$1,819,630

The simplified method assigns a lower cost responsibility to all vehicle classes except pick-up and combination trucks than does the ADOT HCAS model. The cost responsibility of these two classes is increased by the simplified method. Deviation of results produced by the Simplified Model of cost allocation from the ADOT HCAS results are illustrated below. With the exception of pick-ups/SUVs, the variance between the two sets of results is highest for the vehicle classes with the lowest projected cost responsibility. Variance decreases as overall cost responsibility increases. Overall cost responsibility is slightly lower in the simplified methodology. This small difference was not considered significant in the context of the large total sums involved and the inherent uncertainties of a five year forecast.[6]

Table 25: Comparison of Cost Responsibility by Vehicle Class

Vehicle Class	1999 to 2003 Cost Responsibility (Millions)		Simplified % of HCAS Results
	Simplified Model	ADOT HCAS	
Autos	$733.4	$787.89	93%
Pick-ups/SUVs	$358.8	$259.96	138%
Buses	$6.2	$10.97	57%
Single Unit Trucks	$149.5	$202.13	74%
Combination Trucks	$571.7	$563.37	101%
Totals	$1,819.6	$1,824.32	100%

The cost allocation results generated by the simplified method for the various vehicle classes were considered close enough to the results of the HCAS model that an entire simplified model should be attempted as a part of this study. In the following section, conversion of cost responsibility data from vehicle to weight classes is discussed, highlighting only the differences in methods used. A more detailed discussion of the conversion calculations can be found in Appendix C. The cost allocation by weight class

[6] In particular, the ADOT HCAS model applies a complicated series of calculations and assumptions to the Operating Program and the Discretionary Fund in order to project construction expenditures. An effort has been made to duplicate the salient features of the HCAS analysis in the Simplified Model. However, while state and regional (MAG & PAG) expenditures projected by the Simplified Model match those of the HCAS model, the federal apportionment obtained via the Simplified Model is approximately 1 percent lower than projected by the ADOT HCAS.

is followed by a detailed discussion of the second half of the model, the attribution of different sources of projected revenues to vehicles and weight classes.

Cost Allocation by Weight Class

The sources of expenditure data and means of attributing expenditures to the Urban/Common and Rural categories remains the same as described on pages 25 to 27 of this report. However, allocation of cost responsibility to various registered weight classes requires more complicated matrix operations than the allocation among vehicle classes. Assignment of both VMT and ESAL factors was done for each weight class by vehicle configuration, incorporating the registration database from the ADOT HCAS model.

The series of steps required to make these adjustments are discussed in Appendix C of this report, and results of the Simplified Model's allocation of costs by weight are shown in the tables below. One important caveat to the results produced via the methodology explained in Appendix C is that the registration-weighted allocation of VMT implicitly assumes that all vehicles in a given class or configuration average the same amount of travel, *regardless of weight*. While this is unlikely for any particular vehicle/weight category, it is assumed not to have a substantial effect on allocation in the aggregate.

As in the case of cost allocation by vehicle class, the distribution of responsibility for Urban and Common expenditures is skewed toward the lightest vehicle class. The "0 to 8,000 pound" weight class, comprised primarily of autos and pick-ups/SUVs, is projected to be responsible for average annual common costs of roughly $1,090 million over the program period, 79.5 percent of the total expenditures in this category. In comparison, autos and pick-ups had a combined Urban/Common cost responsibility averaging $1,092 million in the allocation by vehicle class.

The second largest allocation of costs occurred in the "75,000 to 80,000 pound" weight class, which is dominated by combination trucks. These vehicles tend to travel much larger distances in a year, and their disproportionately high share of VMT (relative to registrations) is matched by an allocation of 11.3 percent of Urban/Common costs. Because the allocation of these costs is driven solely by VMT, the percentages of VMT for each weight class also represent the total share of Urban/Common costs allocated to that weight class.

Table 26: Allocation by VMT (Urban Expenditures and Common Costs, 1999 to 2003)
(Dollar values in thousands)

Weight Class	Proportion of VMT	Construction Programs	Local Expenditures	Common Costs	Total Allocation
0-8,000 lb.	0.7951	$354,324	$482,135	$253,316	$1,089,774
8,000-10,000 lb.	0.0111	$4,932	$6,711	$3,526	$15,168
10,00 -12,000 lb.	0.0032	$1,441	$1,961	$1,030	$4,432
12,000-14,000 lb.	0.0017	$737	$1,003	$527	$2,267
14,000-16,000 lb.	0.0022	$994	$1,352	$710	$3,056
16,000-18,000 lb.	0.0032	$1,435	$1,952	$1,026	$4,412
18,000-20,000 lb.	0.0031	$1,385	$1,884	$990	$4,259
20,000-22,000 lb.	0.0015	$676	$920	$484	$2,080
22,000-24,000 lb.	0.0043	$1,923	$2,617	$1,375	$5,915
24,000-26,000 lb.	0.0047	$2,091	$2,845	$1,495	$6,431
26,000-28,000 lb.	0.0032	$1,429	$1,944	$1,021	$4,395
28,000-30,000 lb.	0.0024	$1,087	$1,479	$777	$3,342
30,000-32,000 lb.	0.0014	$631	$859	$451	$1,942
32,000-36,000 lb.	0.0020	$899	$1,223	$643	$2,765
36,000-40,000 lb.	0.0028	$1,228	$1,671	$878	$3,777
40,000-45,000 lb.	0.0031	$1,396	$1,900	$998	$4,294
45,000-50,000 lb.	0.0088	$3,904	$5,313	$2,791	$12,008
50,000-55,000 lb.	0.0084	$3,745	$5,095	$2,677	$11,517
55,000-60,000 lb.	0.0109	$4,838	$6,584	$3,459	$14,881
60,000-65,000 lb.	0.0064	$2,832	$3,853	$2,024	$8,709
65,000-70,000 lb.	0.0016	$708	$964	$506	$2,178
70,000-75,000 lb.	0.0056	$2,487	$3,385	$1,778	$7,650
75,000-80,000 lb.	0.1134	$50,514	$68,735	$36,114	$155,363
Total	1.0000	$445,635	$606,384	$318,597	$1,370,616

The allocation of Rural expenditures for the 1999 to 2003 program period by weight class is shown in the following table. All allocations by the Rural method are weighted by VMT and ESAL factors for each vehicle/weight class combination, which are then added together for each weight class and scaled to 100 percent to obtain a weighted allocation factor. Just as with the Rural allocation by vehicle class, the heavier end of the configuration spectrum is allocated a far higher proportion of cost responsibility. However, due to the much higher number of weight classes than vehicle classes, VMT breakdown by specific axle configuration plays a more important role in the allocation of Rural expenditures by weight.

Table 27: Allocation by ESAL (Rural Expenditures, 1999 to 2003)
(Dollar values in thousands)

Weight Class	Proportion of VMT	Weighted Allocation Factor	Construction Programs	Local Expenditures	Total Allocation
0-8,000 lb.	0.7059	0.0001	$18	$7	$26
8,000-10,000 lb.	0.0095	0.0001	$33	$14	$47
10,000-12,000 lb.	0.0044	0.0001	$20	$8	$27
12,000-14,000 lb.	0.0021	0.0001	$19	$8	$26
14,000-16,000 lb.	0.0030	0.0002	$49	$20	$68
16,000-18,000 lb.	0.0042	0.0003	$109	$44	$153
18,000-20,000 lb.	0.0041	0.0005	$172	$70	$242
20,000-22,000 lb.	0.0021	0.0004	$119	$48	$168
22,000-24,000 lb.	0.0061	0.0013	$408	$166	$574
24,000-26,000 lb.	0.0063	0.0023	$722	$293	$1,015
26,000-28,000 lb.	0.0042	0.0020	$645	$262	$907
28,000-30,000 lb.	0.0033	0.0017	$547	$222	$769
30,000-32,000 lb.	0.0022	0.0011	$341	$138	$479
32,000-36,000 lb.	0.0026	0.0018	$581	$236	$816
36,000-40,000 lb.	0.0039	0.0028	$910	$369	$1,279
40,000-45,000 lb.	0.0038	0.0020	$649	$263	$912
45,000-50,000 lb.	0.0103	0.0135	$4,318	$1,751	$6,070
50,000-55,000 lb.	0.0109	0.0156	$4,981	$2,020	$7,001
55,000-60,000 lb.	0.0183	0.0403	$12,868	$5,219	$18,087
60,000-65,000 lb.	0.0096	0.0259	$8,288	$3,361	$11,649
65,000-70,000 lb.	0.0026	0.0110	$3,525	$1,430	$4,955
70,000-75,000 lb.	0.0088	0.0173	$5,526	$2,241	$7,767
75,000-80,000 lb.	0.1718	0.8596	$274,607	$111,373	$385,980
Total	1.0000	1.0000	$319,453	$129,561	$449,015

The total cost responsibility by weight class represents the sum of Urban/Common and Rural expenditures allocated to weight classes in the preceding sections. Relative to the allocation of Local Expenditures and Common Costs spending, responsibility for the expenditures in the 1999 to 2003 Construction Programs is allocated to heavy vehicles in greater proportions. Much of the current Construction Program expenditures were classified as "rural," which was weighted according to ESAL. As shown in Appendix A, the output of the ADOT HCAS had a "construction costs" allocation more skewed toward heavy vehicles than in previous periods as well (HCAS Table 3, page 62). This similarity provides further justification for the validity of the simplified methodology. Total cost responsibility for 1999 to 2003 expenditures by weight class and expenditure category are shown in the table below.

Table 28: Annual Cost Responsibility by Weight Class (Simplified Methodology)
(Dollar values in thousands)

Weight Class	Construction Programs	Local Expenditures	Common Costs	Total Responsibility
0-8,000 lb.	$354,342	$482,142	$253,316	$1,089,799
8,000-10,000 lb.	$4,965	$6,724	$3,526	$15,215
10,000-12,000 lb.	$1,461	$1,969	$1,030	$4,460
12,000-14,000 lb.	$756	$1,010	$527	$2,293
14,000-16,000 lb.	$1,042	$1,372	$710	$3,125
16,000-18,000 lb.	$1,543	$1,996	$1,026	$4,565
18,000-20,000 lb.	$1,557	$1,954	$990	$4,500
20,000-22,000 lb.	$796	$969	$484	$2,248
22,000-24,000 lb.	$2,331	$2,782	$1,375	$6,489
24,000-26,000 lb.	$2,813	$3,138	$1,495	$7,446
26,000-28,000 lb.	$2,074	$2,206	$1,021	$5,301
28,000-30,000 lb.	$1,633	$1,700	$777	$4,111
30,000-32,000 lb.	$972	$997	$451	$2,420
32,000-36,000 lb.	$1,480	$1,459	$643	$3,581
36,000-40,000 lb.	$2,138	$2,040	$878	$5,056
40,000-45,000 lb.	$2,045	$2,163	$998	$5,206
45,000-50,000 lb.	$8,222	$7,064	$2,791	$18,078
50,000-55,000 lb.	$8,726	$7,116	$2,677	$18,518
55,000-60,000 lb.	$17,706	$11,802	$3,459	$32,968
60,000-65,000 lb.	$11,119	$7,214	$2,024	$20,358
65,000-70,000 lb.	$4,233	$2,393	$506	$7,133
70,000-75,000 lb.	$8,013	$5,626	$1,778	$15,417
75,000-80,000 lb.	$325,121	$180,108	$36,114	$541,343
Total	$765,088	$735,945	$318,597	$1,819,630

The Simplified Model assigns greater cost responsibility to the lightest vehicle class (due primarily to its higher projection of responsibility on the part of pick-ups) and to several intermediate weight classes than does the ADOT HCAS. For vehicles weighing between 8,000 and 22,000 pounds, the Simplified Model assigns a far lower cost responsibility (about 46 percent) than does the ADOT HCAS. While disparities isolated by weight class are quite large (as in the case above, the 28,000 to 40,000 pound classes and the 55,000 to 60,000 pound class), a good deal of variation may be attributable to the very small cost responsibilities associated with these weight classes due to their small share of total traffic volume.

In general, results tend to be closest in the weight classes with the greatest cost responsibility: the 0 to 8,000 pound weight class and nearly all weight classes greater than 40,000 pounds. A summary of the cost responsibilities allocated by the two models is shown below for aggregated weight classes.

Table 29: Comparison of Cost Responsibility by Weight Class

Weight Class	Annual Cost Responsibility (Millions)		Simplified % of HCAS Results
	Simplified Model	ADOT HCAS	
0-10,000 lb.	$1,105.0	$1,087.8	102%
10,000-20,000 lb.	$18.9	$41.9	45%
20,000-40,000 lb.	$36.7	$68.5	54%
40,000-60,000 lb.	$74.8	$64.7	116%
60,000-75,000 lb.	$42.9	$33.3	129%
75,000-80,000+ lb.	$541.3	$528.1	103%
Total	$1,819.6	$1,824.3	100%

Simplified Revenue Allocation Method

Revenue data used for the Simplified Model were obtained from the ADOT Finance Department. The revenue forecasts used in the Simplified Model are the same "control totals" for the HCAS model as discussed in Appendix A. In the aggregate, there is expected to be no difference in total revenues for each revenue category between the ADOT HCAS and the Simplified Model. State revenues projected by ADOT for the 1999 to 2003 program period are shown by broad revenue category in the table below. Federal fuel tax revenues were calculated based on state fuel tax projections, factored upward by the ratio of federal to state tax rates. Federal sales, use and tire taxes were increased by the compound annual growth rate of these revenues as measured in previous HCAS updates. As in the case of the ADOT HCAS model, the Simplified Model uses an average of annual revenues for the forecast period to make the allocation to vehicles and weight classes.

Table 30: Revenues by Source

Revenue Category	Fiscal Year (Dollars in Millions)					Annual Average
	1999	2000	2001	2002	2003	
State Gas Tax	$377.4	$400.1	$411.5	$422.1	$444.0	$411.0
State Use Fuel Tax	$148.9	$159.0	$156.9	$161.1	$166.2	$158.4
State Motor Carrier Tax	$38.3	$46.7	$47.6	$48.6	$49.5	$46.2
State Vehicle License Tax	$647.6	$644.5	$696.8	$755.6	$819.3	$712.8
State Registration Fees	$132.8	$137.1	$141.5	$144.3	$148.2	$140.8
Other State Taxes and Fees	$38.5	$34.2	$35.3	$36.1	$37.0	$36.2
Federal Gas Tax	$385.8	$409.0	$420.6	$431.5	$453.8	$420.1
Federal Diesel Tax	$201.8	$215.6	$212.6	$218.4	$225.3	$214.7
Federal Sales Tax	$29.3	$31.0	$32.9	$34.8	$36.9	$33.0
Federal Use Tax	$10.9	$11.1	$11.4	$11.6	$11.9	$11.4
Federal Tire Tax	$5.7	$5.8	$6.0	$6.1	$6.2	$6.0
Total (Millions)	$2,017.0	$2,093.9	$2,173.0	$2,270.2	$2,398.2	$2,190.4

Each of the revenue categories shown in the table were allocated to vehicle and weight classes based on different criteria. In general, the means of allocation followed the methods of the ADOT HCAS model. Fuel revenues were allocated based on VMT and relative fuel efficiency of vehicle classes and weight classes. The motor carrier tax was assigned to commercial vehicles based on the proportion of registrations in each category weighted by the differential in motor carrier fees assessed by weight. The vehicle license tax, registration fees and other miscellaneous taxes and fees required the addition of external data sets, as well as a more detailed breakdown of the latter two categories in order to make an accurate allocation. Methods used to assign all fees to vehicle and weight classes are discussed in greater detail in the following sections. Summary tables of average annual revenues from 1999 to 2003 allocated by vehicle and weight classes are shown on pages 41 and 42.

Allocation of State and Federal Fuel Taxes

The initial allocation of gasoline and diesel fuel taxes for the program period was made under the assumption that an insignificant portion of gasoline taxes would be paid by commercial vehicles (i.e. buses, single unit and combination trucks), and that a similarly small percentage of diesel fuel taxes would be attributable to autos and pick-ups. Based on this assumption, the allocation of fuel taxes was split between "commercial" and "non-commercial" vehicles, with the former being allocated 100 percent of diesel revenues and the latter being assigned 100 percent of gasoline revenues. This initial allocation was made solely for the sake of simplicity in working with registration and weight databases.

Gasoline taxes were allocated among autos and pick-ups using a combination of VMT and relative fuel efficiency. Fuel efficiency data were obtained from the updated ADOT HCAS data. Autos were assigned a default fuel efficiency of 22.2 miles per gallon and pick-ups were assigned an MPG of 15.1. Autos were thus rated as 48 percent more fuel-efficient than pick-ups. This differential was applied to the share of VMT of each vehicle class, and the final ratio was then used to allocate gasoline tax revenues to autos and pick-ups. Autos were allocated a final share of 58.5 percent of gasoline tax revenues and pick-ups were assigned the remaining 41.5 percent. In comparison, these vehicles accounted for 67.6 percent and 32.4 percent of "non-commercial" traffic respectively.[7]

Gasoline taxes were allocated by weight class based on a weighted average of the two vehicle class' fuel efficiencies and the proportion of "non-commercial" travel for each weight class. The weighted average fuel efficiency was 19.9 miles per gallon, applied to all non-commercial vehicles' share of each weight class. Virtually 100 percent of gasoline tax revenues were allocated to vehicles weighing less than 8,000 pounds, due to the proportional representation of this weight class in the registration and VMT data sets for autos and pick-ups.

Diesel taxes were distributed among buses, single unit and combination trucks using a similar approach. However, in this case, standardized fuel efficiencies had to be assigned based on MPG estimates for each weight class by vehicle type weighted by that weight class's proportion of VMT by vehicle type. For example, fuel efficiencies assigned by the ADOT HCAS model by weight class and vehicle configuration are identical for buses and single unit trucks. However, most travel by buses was reported for vehicles weighing between 8,000 and 12,000 pounds. While the 8,000 to 10,000 pound weight class also represents the largest share of travel by single unit trucks, these vehicles reported higher proportional shares of travel in heavier, less fuel-efficient weight classes than buses. Therefore, buses were assigned a slightly more efficient MPG than single unit trucks. A fuel efficiency of 8.8 MPG was assigned to buses, and single unit and combination trucks were assigned fuel efficiencies of 8.3 MPG and 5.9 MPG respectively. The final shares of

[7] Note that the ADOT HCAS results do not reflect a fuel efficiency differential between these two vehicle classes, despite reporting the MPG estimates listed above. The ADOT HCAS allocation of fuel taxes to these two vehicle classes appears nearly identical to their shares of VMT. Therefore results of the two models will differ substantially in allocation of the gasoline tax.

diesel revenues attributed to these vehicle classes, weighted by MPG and share of travel, were 1.4 percent to buses, 21.8 percent to single unit trucks, and 76.8 percent to combinations.

Diesel fuel revenues were allocated among weight classes based on the "commercial" VMT assigned to each weight class and configuration, factored by the MPG assigned to each combination. The heaviest weight class, made up mostly of combination trucks, was assigned the majority share of diesel fuel revenues (61.8 percent), based on the relatively poor fuel efficiency and high share of "commercial" VMT attributable to these vehicles. Vehicles with registered weights between 45,000 and 75,000 pounds were allocated most of the remaining diesel revenues (21.2 percent), although no weight class other than the heaviest was allocated more than 6 percent of total diesel revenues. Vehicles with registered weight below 26,000 pounds made up only 10.8 percent of the diesel fuel allocation.

Allocation of State Motor Carrier Fees

Motor carrier fees were assigned solely to single unit and combination trucks. The average annual revenue allocation for motor carrier fees from 1999 to 2003 totaled $46.2 million. These revenues were split among single unit and combination trucks according to a combination of relative magnitude of fees applicable to vehicles by registered weight and the proportion of "commercial" registrations by weight and vehicle type.

Motor carrier fees ranging from $64 for commercial vehicles between 12,001 and 14,000 pounds to $800 for vehicles registered above 75,000 pounds were first assigned a proportional weighting of relative magnitude. If, for example, the two fees mentioned above were the only fees applicable to vehicles weighing either above or below 75,000 pounds, then a vehicle in the upper weight category would be assigned a proportional amount of motor carrier fees (per registration) of: $800 ÷ ($800 + $64) = 0.926. The lighter vehicle category would be assigned a motor carrier factor of 0.074. The actual factors applied to each weight category simply reflect the proportional difference between fees assessed at each weight level.

Proportional distributions of motor carrier fees by relative magnitude were used to factor the distribution of registrations either upward or downward as follows: the motor carrier factor discussed above was multiplied by the share of registrations for each vehicle type (single unit or combination) and weight class. All of these results were then scaled to 100 percent of the total motor carrier fee, and each scaled proportion was used to assign a percentage of the motor carrier tax to a truck type and weight combination. Because combination trucks tend to have much higher registered weights than single unit trucks, the majority of motor carrier fees were assigned to combination trucks, despite their relatively small share of commercial registrations. Similar results were obtained for weight classes, with the distribution of motor carrier fees skewed toward the heaviest weight class.

Allocation of the Arizona Vehicle License Tax

Because of the large amount of variance inherent in vehicle values (upon which the VLT is based), the initial distribution of VLT was made among broad vehicle categories according to historical percentages of VLT attributable to these vehicle types. VLT collections for fiscal years 1992 to 1998 were obtained for autos (including motorcycles), pick-ups and vans, buses and commercial trucks (including trailers, which were broken out separately for further analysis). With the exception of commercial trucks, for which additional calculations were necessary in order to separate VLT by single unit and combination classes, the average percentage of total VLT collected that was attributable to a particular vehicle class from 1992 to 1998 was used as a baseline from which to distribute VLT for the 1999 to 2003 program period. Averages for each vehicle type were adjusted upward or downward according to historical growth or decline over the base period. Pick-ups had the highest annual rate of growth in VLT collections (4.1 percent), so the base period average for pick-ups was factored upward accordingly. The decline in share of VLT attributed to autos is not the result of negative growth, but rather in faster growth in other vehicle classes, most of which has been reallocated to pick-ups in the program period. Base period and program period VLT distributions are shown in the following table.

Table 31: VLT by Vehicle Class

Vehicle Class	Average Share of VLT	
	Base Period, 1992 to 1998	Program Period, 1999 to 2003
Autos	0.7474	0.7374
Pick-ups	0.1182	0.1309
Buses	0.0004	0.0003
Commercial Trucks	0.1262	0.1236
Commercial Trailers	0.0078	0.0079
Total	1.0000	1.0000

Autos and pick-ups were assigned shares of VLT based on the each vehicle class' share of the sum of their respective VLT attributions shown above *and* on the share of registrations attributable to each. This adjustment was made in an effort t approximate growth in the volume of transactions as well as the value of each transaction, which was highest for pick-ups and vans and increased the share of these vehicles slightly in the final allocation. Buses received an allocation of VLT based on the ratio shown above.

In order to allocate the commercial share of VLT to single unit and combination trucks, scaled ratios of estimated vehicle prices were used based on inflation adjusted results of the original HCAS. These valuation ratios were used in a manner similar to the weight adjustment used to distribute motor carrier fees. The average price of single unit and combination trucks by registered weight was used to factor the number of registrations of each vehicle type by weight category. Ratios obtained via this method were used to

distribute the 12.6 percent of VLT assigned to "Commercial Trucks" as shown in the table above. "Commercial Trailers" VLT was distributed among combination trucks only, under the assumption that "single unit" trucks should be excluded by definition.

From the distribution of VLT by vehicle class, allocation to various weight classes was made using the proportion of registrations in each weight class by vehicle type and then summing the results. Note that with the exception of commercial trucks, this method assumed uniform average values among vehicle classes, regardless of weight. However, in the case of pick-ups and autos, virtually all registrations were in the lightest category; and while buses are distributed across a variety of weight classes, their contribution to total VLT is minuscule. For these reasons, the scaling of vehicle valuations by weight was not considered necessary for distributing VLT for these vehicles.

Allocation of State Registration Fees

Registration fees were broken down for the HURF forecast into sub-categories that were useful for this analysis. The first category, "Registration and Weight Fees," is further subdivided into its respective attributes based on 1999 forecast distribution ratios. For the purpose of this analysis, the "Registration" portion of these fees was considered common to all vehicles, distributed based on share of registrations and adjustments for reduced-fee and government vehicles. A similar assumption was made for the distribution of registration permits and penalties. "Weight" and "Apportioned" fees were assigned only to "commercial" vehicle classes (i.e. buses and trucks), based on a scaling of fees by weight similar to that used for motor carrier fees. "Weight" fees were scaled based on relative magnitude of the registration fee schedule, while "Apportioned" fees were scaled based on the schedule of Use Fees applicable to each weight class. Projected registration fees by sub-category are shown for fiscal 1999 to 2003 in the table below.

Table 32: Registration Fees

Registration Fees	Fiscal Year (Dollars in Millions)					Annual Average
	1999	2000	2001	2002	2003	
Registration & Weight						
Registration	$33.9	$34.9	$36.1	$36.8	$37.8	$35.9
Weight	$23.2	$24.0	$24.8	$25.2	$25.9	$24.6
Apportioned	$65.0	$67.1	$69.3	$70.6	$72.5	$68.9
Reg. Permit & Penalties	$10.7	$11.0	$11.4	$11.6	$11.9	$11.3
Total	$132.8	$137.1	$141.5	$144.3	$148.2	$140.8

All calculations were adjusted for reduced-fee and government vehicles, which were simply used to reduce the overall count of registrations in each vehicle category. The total of full-fee registrations was then used to recalculate ratios of revenue responsibility. Because buses and single unit trucks had the greatest incidence of reduced-fee status among registered vehicles (86.5 percent and 24.7 percent respectively), these two vehicle classes had their shares of registration fee revenues reduced significantly in relation to other vehicle classes.

Because nearly two-thirds of the total fees shown in the table above were allocated only to commercial vehicles ("Weight" and "Apportioned" fees) and were scaled according to a weight-based allocation of revenue responsibility, the final distribution of registration fees is allocated primarily to the heaviest weight classes. Nonetheless, by virtue of the volume of transactions recorded for autos and pick-ups, the Simplified Model allocates roughly 19 percent of registration revenues to the lightest weight class.

Allocation of Other State Taxes and Fees

Other taxes and fees allocated to vehicle and weight classes included title fees, operator licenses and special plates and permits. The various fees shown in the table below are allocated based on the distribution of these fees in ADOT's forecast for fiscal 1999. With the exception of "Oversize Permits" and "Use Fuel Permits," all of the fees shown in the table were considered common fees and were distributed to vehicle classes and weight classes based on the respective share of total registrations attributed to each category. Oversize permits and use fuel permits were allocated among commercial vehicles only, using a matrix of commercial registrations derived from the matrix of proportional shares of all registrations. A total of $4.1 million in annual fees was thus allocated among commercial vehicles only, with the remaining $32.1 million allocated primarily to autos and pick-ups.

Table 33: Other Taxes & Fees

Other Taxes and Fees	Fiscal Year (Dollars in Millions)					Annual Average
	1999	2000	2001	2002	2003	
Title Fees	$5.6	$5.0	$5.1	$5.2	$5.4	$5.3
Operator License	$14.1	$12.5	$12.9	$13.2	$13.6	$13.3
Oversize Permits	$3.2	$2.8	$2.9	$3.0	$3.1	$3.0
Inquiry Fees	$6.7	$6.0	$6.1	$6.3	$6.4	$6.3
Use Fuel Permits	$1.2	$1.1	$1.1	$1.1	$1.2	$1.1
Investment Interest	$2.0	$1.8	$1.8	$1.9	$1.9	$1.9
Special Plates	$3.4	$3.0	$3.1	$3.2	$3.3	$3.2
Misc. Fees	$2.3	$2.0	$2.1	$2.2	$2.2	$2.2
Total	$38.5	$34.2	$35.3	$36.1	$37.0	$36.2

Allocation of Federal Sales, Use and Tire Taxes

Federal sales, use and tire taxes are applicable to commercial vehicles only. For the sake of simplicity, the distribution of these revenues was thus limited to single unit and combination trucks. Federal sales tax revenues were allocated among these vehicles using the same scale of relative valuation applied to the distribution of VLT, recalibrated to incorporate the added value of trailers in the case of combination trucks. Federal tire taxes were allocated among single unit and combination trucks based on the number of 1990 registrations and the estimated tire count for each vehicle configuration. For the

sake of simplicity, all tires taxed were assumed to be the same size, though the federal tire tax is assessed at a higher rates for tires weighing more than 40 pounds.

Federal use taxes, applicable to vehicles registered at 55,000 pounds or more, consist of a base fee of $155 plus $22 for every thousand pounds over 55,000, up to a maximum charge of $550. Each weight class was assessed a scaled tax using the median weight within that class. For example, vehicles in the 70,000 to 75,000 pound weight class were assigned a default tax of $485, based on a median weight of 72,500 pounds. Default taxes for each weight class were then given allocation factors according to relative magnitude of the tax, which were multiplied by single unit and combination registrations and scaled to equal 100 percent.

Simplified Model Revenue Allocation Results

As in the case of the original HCAS model, the Simplified Model allocates the greatest portion of highway user revenues to autos and pick-ups. Of the "non-commercial" vehicle classes, autos are projected to account for $982.5 million annually, or 65.2 percent of "non-commercial" revenues. Autos and pick-ups combined are projected to generate $1,506.7 million annually in highway user revenues, roughly 69 percent of all highway user revenues in the forecast period. Combination trucks represent the next largest source of highway user revenues, about 21 percent, followed by single unit trucks and buses. Revenues generated by the latter two categories reflect a higher incidence of reduced-fee tax status among registered vehicles.

Interestingly, despite the variety of calculations used to allocate different revenue sources among vehicle classes, the overall distribution of highway user revenues is generally close to the share of VMT projected for each vehicle class. Autos comprise about 52 percent of VMT projected for the program period, and are assigned just under 45 percent of revenues. Pick-ups and combinations are projected to account for 25 percent and 17 percent of 1999 to 2003 VMT, and are assigned 24 percent and 21 percent of total highway user revenues over the same period. The allocations of annual revenues by vehicle class and level of government for the 1999 to 2003 program period are shown in the tables below.

Table 34: Simplified Model Annual State Revenue Allocation by Vehicle Class 1999 to 2003

(Dollars in Millions)

Vehicle Class	State Revenues							State Totals
	Gas Tax	Diesel Tax	VLT	Reg. & Weight	Motor Carrier Fee	Other (Non-truck)	Other (Truck)	
Autos	$240.4	$0.0	$454.5	$18.9	$0.0	$22.9	$0.0	$736.8
Pick-ups	$170.6	$0.0	$164.3	$6.6	$0.0	$8.3	$0.0	$349.8
Buses	$0.0	$2.2	$0.2	$0.3	$0.0	$0.1	$0.0	$2.8
Single Units	$0.0	$34.5	$58.5	$30.8	$14.6	$0.7	$3.5	$142.6
Combinations	$0.0	$121.6	$35.2	$84.2	$31.5	$0.1	$0.6	$273.3
Totals	$411.0	$158.4	$712.8	$140.8	$46.2	$32.1	$4.1	$1,505.3

In contrast to the influence of the vehicle license tax and registration fees on state revenues, the distribution of federal revenues is dominated by fuel taxes. Higher diesel tax rates and lower fuel efficiency transfer a greater share of responsibility for federal highway tax revenues to commercial vehicles. Whereas pick-ups/SUVs comprised the second largest source of *state* highway tax revenues, combination trucks comprise the second largest source of federal highway revenues. Autos still generate the largest share of federal highway taxes, 35.9 percent, but are followed closely by combination trucks, 28.1 percent. Pick-ups are projected to generate 25.5 percent of federal highway user revenues from 1999 to 2003, while buses and single unit trucks are expected to generate 0.4 percent and 10.1 percent respectively.

Table 35: Simplified Model Annual Federal Revenue Allocation by Vehicle Class 1999 to 2003

(Dollars in Millions)

Vehicle Class	Federal Revenues					Federal Totals	Total State and Federal Revenues
	Gas Tax	Diesel Tax	Use Tax	Sales Tax	Tire Tax		
Autos	$245.7	$0.0	$0.0	$0.0	$0.0	$245.7	$982.5
Pick-ups	$174.4	$0.0	$0.0	$0.0	$0.0	$174.4	$524.2
Buses	$0.0	$3.0	$0.0	$0.0	$0.0	$3.0	$5.8
Single Units	$0.0	$46.8	$1.2	$20.5	$0.7	$69.3	$211.9
Combinations	$0.0	$164.9	$10.1	$12.4	$5.2	$192.6	$465.9
Totals	$420.1	$214.7	$11.4	$32.9	$6.0	$685.1	$2,190.4

Given the methods of allocating fuel taxes to vehicle and weight classes, it is no surprise that the majority of gasoline tax revenues are allocated to the lightest vehicles and the bulk of diesel revenues are allocated to the heaviest vehicles. The distribution of weight-

based registration and motor carrier fees follow a similar pattern, due to the incremental increases in fee schedules as weight increases. "Common" revenues, those that are paid by highway users regardless of weight considerations, are most concentrated in the lightest weight category. Even VLT revenues follow this pattern, for despite the fact that the average combination truck has a far greater assessed value (upon which the VLT is imposed), the volume of registration transactions in the lightest weight class ensures that VLT, operator license revenues, title fees, etc. will all be most highly represented by passenger vehicles in the lightest weight category.

Distribution of federal revenues is dominated by the method for allocating fuel tax revenues. Gas and diesel imposts represent 92.7 percent of all federal revenues projected for the 1999 to 2003 forecast period. Fuel economy was assigned based on a sliding scale that declined as weight increased, ensuring that the distribution of diesel revenues would be allocated primarily to combination trucks. These vehicles had not only the lowest fuel efficiencies, but also a large share of total commercial VMT.

In the aggregate, vehicles weighing 8,000 pounds or less comprised the largest source of highway user revenues by weight category. Vehicles in this weight class accounted for 72.3 percent of highway user revenues projected for the 1999 to 2003 period. The vast majority (94.5 percent) of revenues attributed to these vehicles came from just two sources: the vehicle license tax and gasoline taxes. The same two revenue sources generally made up the largest share of revenues collected from all weight classes, but the importance of these two revenue sources tends to decline as weight increases. This is due to the low registration counts in many heavier weight classes, and the rising share of weight-based revenues in the overall allocation. While diesel fuel taxes remain the largest single source of revenues (46.2 percent) collected from the heaviest weight class, the VLT (13.5 percent) has been surpassed by weight-based registration fees (29.5 percent) in terms of revenues collected from this weight class.

Table 36: Simplified Model Revenue Allocation by Weight Class, 1999 to 2003
(Dollars in Millions)

Weight Class	State Revenues							State Totals
	Gas Tax	Diesel Tax	Use Tax	Sales Tax	Motor Carrier Fee	Other (Non-truck)	Other (Truck)	
0-8,000 lb.	$410.9	$1.5	$618.7	$26.8	$0.0	$31.2	$0.0	$1,089.0
8,000-10,000 lb.	$0.0	$2.9	$11.2	$4.6	$0.0	$0.3	$1.3	$20.3
10,000-12,000 lb.	$0.0	$1.4	$4.1	$1.7	$0.0	$0.1	$0.4	$7.7
12,000-14,000 lb.	$0.1	$0.7	$1.2	$0.6	$0.3	$0.0	$0.1	$3.0
14,000-16,000 lb.	$0.0	$1.1	$2.4	$1.1	$0.8	$0.0	$0.2	$5.7
16,000-18,000 lb.	$0.0	$1.6	$2.0	$0.9	$0.7	$0.0	$0.1	$5.3
18,000-20,000 lb.	$0.0	$1.6	$3.9	$1.8	$1.4	$0.1	$0.2	$9.0
20,000-22,000 lb.	$0.0	$0.8	$1.1	$0.5	$0.4	$0.0	$0.1	$3.0
22,000-24,000 lb.	$0.0	$2.6	$2.1	$1.0	$0.7	$0.0	$0.1	$6.6
24,000-26,000 lb.	$0.0	$2.8	$7.5	$4.2	$2.6	$0.1	$0.4	$17.6
26,000-28,000 lb.	$0.0	$1.9	$1.3	$0.8	$0.5	$0.0	$0.1	$4.6
28,000-30,000 lb.	$0.0	$1.5	$1.7	$1.3	$0.6	$0.0	$0.1	$5.1
30,000-32,000 lb.	$0.0	$1.0	$1.2	$1.2	$0.4	$0.0	$0.0	$4.0
32,000-36,000 lb.	$0.0	$1.3	$2.0	$1.8	$0.7	$0.0	$0.1	$5.9
36,000-40,000 lb.	$0.0	$2.0	$1.6	$1.4	$0.5	$0.0	$0.0	$5.6
40,000-45,000 lb.	$0.0	$2.2	$1.4	$1.5	$0.8	$0.0	$0.0	$5.9
45,000-50,000 lb.	$0.0	$6.2	$4.2	$4.8	$2.3	$0.0	$0.1	$17.8
50,000-55,000 lb.	$0.0	$6.4	$7.1	$8.3	$4.1	$0.0	$0.2	$26.0
55,000-60,000 lb.	$0.0	$9.3	$2.2	$2.6	$1.3	$0.0	$0.0	$15.5
60,000-65,000 lb.	$0.0	$5.3	$2.5	$3.3	$1.9	$0.0	$0.0	$13.1
65,000-70,000 lb.	$0.0	$1.4	$1.5	$1.9	$1.1	$0.0	$0.0	$6.0
70,000-75,000 lb.	$0.0	$4.8	$3.2	$6.1	$2.6	$0.0	$0.1	$16.9
75,000-80,000 lb.	$0.0	$97.8	$28.6	$62.5	$22.4	$0.1	$0.5	$211.8
Total	$411.0	$158.4	$712.8	$140.8	$46.2	$32.1	$4.1	$1,505.3

With respect to the federal tire and sales taxes allocated by weight class in the table below, several points bear mentioning. Although a positive correlation was made between commercial vehicle weight and valuation for sales tax purposes, the 8,000 to 10,000 pound weight class made up nearly 12 percent of projected federal sales tax revenues. This observation is due to the fact that, despite their relatively small valuations, vehicles under 10,000 pounds comprised more than 32 percent of all commercial registrations and the majority of single unit trucks. In the case of the tire tax, responsibility falls almost exclusively on the heaviest weight class, even though no adjustment was made for differential fees by tire weight. The added number of axles and proportionally high number of combinations in the heaviest weight class ensured that the distribution of tire tax revenues would fall almost entirely on these vehicles without scaling the tax rate according to tire weight.

Table 37: Simplified Model Annual Federal Revenue Allocation by Vehicle Class 1999 to 2003

(Dollars in Millions)

Vehicle Class	Federal Revenues					Federal Totals	Total State and Federal Revenues
	Gas Tax	Diesel Tax	Use Tax	Sales Tax	Tire Tax		
0-8,000 lb.	$420.0	$2.0	$0.0	$0.0	$0.0	$422.0	$1,511.0
8,000-10,000 lb.	$0.0	$4.0	$0.0	$3.9	$0.1	$8.0	$28.3
10,000-12,000 lb.	$0.0	$1.9	$0.0	$1.4	$0.0	$3.4	$11.2
12,000-14,000 lb.	$0.1	$0.9	$0.0	$0.4	$0.0	$1.4	$4.4
14,000-16,000 lb.	$0.0	$1.5	$0.0	$0.8	$0.0	$2.4	$8.1
16,000-18,000 lb.	$0.0	$2.2	$0.0	$0.7	$0.0	$2.9	$8.3
18,000-20,000 lb.	$0.0	$2.2	$0.0	$1.3	$0.0	$3.6	$12.6
20,000-22,000 lb.	$0.0	$1.1	$0.0	$0.4	$0.0	$1.6	$4.5
22,000-24,000 lb.	$0.0	$3.5	$0.0	$0.7	$0.0	$4.3	$10.8
24,000-26,000 lb.	$0.0	$3.8	$0.0	$2.6	$0.1	$6.4	$24.0
26,000-28,000 lb.	$0.0	$2.6	$0.0	$0.5	$0.0	$3.1	$7.7
28,000-30,000 lb.	$0.0	$2.1	$0.0	$0.6	$0.0	$2.7	$7.8
30,000-32,000 lb.	$0.0	$1.3	$0.0	$0.4	$0.0	$1.8	$5.7
32,000-36,000 lb.	$0.0	$1.8	$0.0	$0.7	$0.0	$2.5	$8.4
36,000-40,000 lb.	$0.0	$2.7	$0.0	$0.6	$0.0	$3.2	$8.8
40,000-45,000 lb.	$0.0	$3.0	$0.0	$0.5	$0.0	$3.5	$9.4
45,000-50,000 lb.	$0.0	$8.5	$0.0	$1.5	$0.1	$10.1	$27.8
50,000-55,000 lb.	$0.0	$8.7	$0.0	$2.5	$0.1	$11.2	$37.2
55,000-60,000 lb.	$0.0	$12.6	$0.3	$0.8	$0.1	$13.8	$29.3
60,000-65,000 lb.	$0.0	$7.2	$0.3	$0.9	$0.1	$8.5	$21.6
65,000-70,000 lb.	$0.0	$1.9	$0.1	$0.5	$0.0	$2.6	$8.5
70,000-75,000 lb.	$0.0	$6.6	$0.5	$1.1	$0.2	$8.3	$25.2
75,000-80,000 lb.	$0.0	$132.6	$10.2	$10.2	$4.7	$157.7	$369.5
Total	$420.1	$214.7	$11.4	$32.9	$6.0	$685.1	$2,190.4

Just as was noted in the allocation of revenues by vehicle class, the share of VMT attributable to a particular weight class is often close to the share of revenues allocated that weight class by the simplified model. However, while a simple allocation based on VMT might be useful for making a rough estimate of revenues attributable to a particular vehicle or weight class, the attribution of many highway user fees according to such a method would be theoretically flawed. Flat fees such as the most recent Arizona motor carrier fee (which replaced a weight-distance tax on heavy commercial vehicle traffic) impose a greater burden on vehicles that travel less, shifting cost responsibility from frequent highway users to infrequent users. To allocate revenues based on VMT, even as a rough proxy, would ignore the differential impact imposed on highway users by a flat

fee structure or a value-based tax such as the VLT (which has no direct relationship to actual highway use).

In most cases, the results of the Simplified Model revenue allocation by vehicle class are close to the results produced by the ADOT HCAS model. Revenues allocated to "non-commercial" autos and pick-ups are distributed differently, with the Simplified Model allocating a larger share to pick-ups and the ADOT HCAS allocating a larger percentage to autos. In the aggregate, results of the two approaches are close, varying by less than 2 percent in an average year. A similar aggregate outcome is obtained by the allocation to single unit and combination trucks, but in this case the variance is larger. In particular, the Simplified Model allocates 16 percent more revenue to single unit trucks than does the ADOT HCAS. Allocation of revenues to buses shows the largest amount of variance between the two models, but the tiny share of total revenues in either case argues that this is not a significant discrepancy for the aggregate analysis.

Table 38: Comparison of Revenue Allocations by Vehicle Class

Vehicle Class	1999-2003 Annual Revenues (Millions)		Simplified % of HCAS Results
	Simplified Model	ADOT HCAS	
Autos	$982.5	$1,021.6	96%
Pick-ups/SUVs	$524.2	$452.9	116%
Buses	$5.8	$9.9	59%
Single Unit Trucks	$211.9	$182.0	116%
Combination Trucks	$465.9	$524.0	89%
Totals	$2,190.4	$2,190.4	100%

A comparison of the revenue allocation by weight class produced by the two models further highlights the impact that buses and single unit trucks have on the distribution of revenues and variance between the two models. The greatest levels of difference between the two revenue allocations occur in the intermediate weight classes that are largely made up of bus and single unit truck registrations. The persistent over-allocation of the Simplified Model relative to the ADOT HCAS suggests that additional fee reductions for single unit trucks were most likely factored into the ADOT HCAS model. However, it is encouraging that both models produce closer results for the weight classes generating the majority of highway user revenues. Aggregated results of the lightest (0 to 10,000 pounds) and heaviest (75,000 pounds or more) weight classes in the Simplified Model are within 4 percent of the ADOT HCAS results.

Table 39: Comparison of Revenue Allocations by Weight Class			
Weight Class	1999-2003 Annual Revenues (Millions)		Simplified % of HCAS Results
	Simplified Model	ADOT HCAS	
0-10,000 lb.	$1,539.4	$1,513.9	102%
10,000-20,000 lb.	$44.6	$44.4	100%
20,000-40,000 lb.	$77.9	$64.9	120%
40,000-60,000 lb.	$103.8	$65.1	159%
60,000-75,000 lb.	$55.3	$41.0	135%
75,000-80,000+ lb.	$369.5	$461.0	80%
Total	$2,190.4	$2,190.4	100%

A great deal more variation exists between attributions of individual revenue sources to vehicle and weight classes in the two models. Fuel tax revenues generally show the least amount of variance, although the relative fuel efficiencies for autos and pick-ups used in the Simplified Model were apparently not used to allocate gasoline revenues in the ADOT HCAS model (see also page 35). Motor carrier and "other" fees, aggregated in the tables below because the ADOT HCAS results required the inclusion of motor carrier fees in the "Other Truck VMT" category, also generally exhibit acceptable levels of variance, with the exception of buses.

Vehicle license taxes and registration fees have much higher levels of variance. However, in most cases over and under-payment between the two models tends to cancel out. When added together, VLT and registration revenues allocated to autos in the simplified model total 98 percent of the corresponding allocation by the ADOT HCAS. Aggregated ratios for pick-ups and combination trucks are 87 percent and 89 percent respectively. However, large discrepancies persist in the aggregate for buses and single unit trucks.

Table 40: Ratios of Simplified Model to HCAS Revenue Projections, 1999 to 2003

Vehicle Class	State Revenues				Total State	Total Federal	All Sources
	Fuel Tax	Motor Carrier & Other Fees	License Tax	Reg. Fees			
Autos	95%	88%	96%	211%	97%	95%	96%
Pickups	140%	89%	85%	166%	107%	140%	116%
Buses	58%	518%	16%	138%	52%	67%	59%
SU	63%	127%	192%	399%	132%	93%	116%
CB	90%	101%	237%	70%	91%	87%	89%
Total	100%	100%	100%	100%	100%	100%	100%

The inclusion of federal tax revenues tends to skew the variation measured for aggregated state revenue sources toward the ratios measured for fuel taxes. In total, this tends to increase variance slightly between the Simplified Model and ADOT HCAS model results in the case of autos, pick-ups and combination trucks, while reducing variance between

models in revenues attributed to buses and single-unit trucks. This is most likely the result of a "smoothing" of the higher levels of variance measured for the state VLT and registration fees.

A weight-based comparison of individual revenue sources returns similar results. Variation is generally lowest for the lightest and heaviest vehicles, which also tend to be the source of the most revenues and the greatest proportion of VMT. Relative to the ADOT HCAS, the Simplified Model over-allocates registration and weight-based fees to intermediate weight and lighter vehicles. All revenue sources except fuel taxes are allocated in greater proportions to intermediate-weight vehicles by the Simplified Model, again most likely due to a relative under-assessment of the impact of tax status on vehicle revenues in these weight categories, particularly single unit trucks. In the aggregate, revenues attributed to the lightest weight classes by the Simplified Model are nearly equal to the allocation made by the ADOT HCAS. Revenues allocated to the heaviest weight class by the Simplified Model equate to roughly 80 percent of the ADOT HCAS allocation.

Table 41: Ratio of Simplified Model to HCAS Revenue Projections, 1999 to 2003

Weight Class	State Revenues				Total State	Total Federal	All Sources
	Fuel Tax	Motor Carrier & Other Fees	License Tax	Reg. Fees			
0-10,000 lb.	107%	81%	94%	232%	99%	108%	102%
10,000-20,000 lb.	44%	108%	188%	342%	110%	84%	100%
20,000-40,000 lb.	71%	169%	193%	208%	132%	102%	120%
40,000-60,000 lb.	148%	240%	206%	178%	176%	137%	159%
60,000-75,000 lb.	113%	263%	191%	180%	160%	105%	135%
75,000-80,000+ lb.	83%	83%	213%	60%	81%	80%	80%
Total	100%	100%	100%	100%	100%	100%	100%

Based on the comparison of revenues attributed to different vehicles and weight classes by the two models, it appears that the greatest disparity of results lies in the allocation of commercial revenues among single unit and combination trucks. While the disparate shares of VLT revenues allocated to different vehicle classes are also cause for concern, the historical trends used for estimation in the Simplified Model provide a greater degree of certainty from which to evaluate future distributions. In any case, the ultimate analysis lies in the estimation of equity in the current highway user fee structure. The following section of this report discusses the user revenue-to-cost responsibility ratios produced by the Simplified Model and then compares these measures of equity to the results of the ADOT HCAS model.

Simplified Model Results and Discussion

As in the case of the ADOT HCAS model, the Simplified Model projects overpayment of highway user fees by autos and pick-ups for the 1999 to 2003 period. Fees paid by autos are expected to exceed their cost responsibility by $245.5 million annually over the forecast period, an annual overpayment averaging 33 percent. Pick-ups are projected to pay taxes and fees that exceed their cost responsibility by an average of 45 percent annually. Buses and combination trucks are expected to pay less than the costs they impose on the highway system over the forecast period, paying an average of 93 percent and 81 percent of their forecast cost responsibility annually. In contrast with the ADOT HCAS model, the Simplified Model forecasts substantial overpayment of cost responsibility by single unit trucks over the forecast period.

Table 42: Simplified Model: Average Annual User Revenues and Cost Responsibility by Vehicle Class, 1999-2003
(Millions of Dollars)

Vehicle Class	User Revenue	Cost Responsibility	Ratio
Autos	$982.5	$737.0	133%
Pick-ups	$524.2	$360.6	145%
Buses	$5.8	$6.3	93%
Single-unit Trucks	$211.9	$150.8	141%
Combination Trucks	$465.9	$577.6	81%
Totals	$2,190.4	$1,832.3	120%

The final revenue-to-cost responsibility results of the Simplified Model appear to be heavily influenced by the relatively high allocation of revenues and low allocation of costs to single unit trucks. Revenue-to-cost responsibility ratios by weight class generated by the Simplified Model project high levels of overpayment of cost responsibility by every weight class up to 55,000 pounds. In many cases, vehicles in a given weight class (e.g. 14,000 to 16,000 pounds) are projected to pay more than twice their cost responsibility from 1999 to 2003. Virtually all weight classes are thus projected to subsidize underpayment by the vehicles weighing 55,000 to 65,000 pounds and vehicles registered at 75,000 pounds or more.

The most significant shortfall in revenues to cost responsibility is projected for the heaviest weight class. Vehicles registered at 75,000 pounds or more are forecast to pay less than 70 percent of their cost responsibility from 1999 to 2003. The revenue shortfall attributed to this weight class is expected to average nearly $178 million annually, with most of the cost of subsidizing the underpayment falling on the lightest weight class. Vehicles weighing less than 8,000 pounds are forecast to pay an average of $416 million more than their cost responsibility each year from 1999 to 2003.

Table 43: Simplified Model: Average Annual User Revenues and Cost Responsibility by Weight Class, 1999-2003

(Millions of Dollars)

Weight Class	User Revenue	Cost Responsibility	Ratio
0-8,000 lb.	$1,511.0	$1,095.2	138%
8,000-10,000 lb.	$28.3	$15.3	185%
10,000-12,000 lb.	$11.2	$4.5	249%
12,000-14,000 lb.	$4.4	$2.3	193%
14,000-16,000 lb.	$8.1	$3.1	257%
16,000-18,000 lb.	$8.3	$4.6	180%
18,000-20,000 lb.	$12.6	$4.5	279%
20,000-22,000 lb.	$4.5	$2.3	201%
22,000-24,000 lb.	$10.8	$6.5	166%
24,000-26,000 lb.	$24.0	$7.5	320%
26,000-28,000 lb.	$7.7	$5.3	144%
28,000-30,000 lb.	$7.8	$4.1	188%
30,000-32,000 lb.	$5.7	$2.4	235%
32,000-36,000 lb.	$8.4	$3.6	234%
36,000-40,000 lb.	$8.8	$5.1	173%
40,000-45,000 lb.	$9.4	$5.2	180%
45,000-50,000 lb.	$27.8	$18.2	153%
50,000-55,000 lb.	$37.2	$18.7	199%
55,000-60,000 lb.	$29.3	$33.3	88%
60,000-65,000 lb.	$21.6	$20.6	105%
65,000-70,000 lb.	$8.5	$7.2	119%
70,000-75,000 lb.	$25.2	$15.6	162%
75,000-80,000 lb.	$369.5	$547.2	68%
Total	$2,190.4	$1,832.3	120%

For most vehicle classes, the discrepancies between highway user revenues and cost responsibilities forecast by the ADOT HCAS model and the Simplified Model tend to cancel each other out when overall equity ratios in the two models are compared. As indicated in the table below, the final revenue-to-cost responsibility ratios for the two models are similar for most vehicle classes. Forecast equity ratios for autos, combination trucks and buses produced by the two models are quite close, with nearly identical results in the first case. Results for pick-ups/SUVs are less closely coordinated, although much of the responsibility for this differential (and that of autos) can be attributed to the inclusion or exclusion of fuel economy when allocating revenues to these vehicles.

The greatest difficulty of the Simplified Model in replicating the results of the ADOT HCAS model can be assigned to the allocation of revenues and cost responsibility to single unit trucks. The Simplified Model assigns only 74 percent of the corresponding

cost responsibility attributed to these vehicles by the ADOT HCAS model, and allocates approximately 16 percent more revenues to single unit trucks. The combined differential produces a revenue-to-cost responsibility ratio for single unit trucks in the Simplified Model that exceeds the equity forecast in the ADOT HCAS model by over 55 percent. In a simpler (but perhaps more important) assessment, the Simplified Model projects *over*payment of highway user revenues by single unit trucks, whereas the ADOT HCAS model forecasts *under*payment by this vehicle class.

Table 44: Equity Ratios of Simplified Model Compared to ADOT HCAS Results

Vehicle Class	Equity Ratios		Equity Comparison[1]
	Simplified Model	ADOT HCAS Model	
Autos	133%	130%	103%
Pick-ups/SUVs	145%	174%	83%
Buses	93%	90%	103%
Single Unit Trucks	141%	90%	156%
Combination Trucks	81%	93%	87%
Total	120%	120%	100%

Note: 1. Simplified Model equity ratio divided by the ADOT HCAS model equity ratio.

The divergence of equity projections for single unit trucks is largely to blame for high variance in the two models' outputs by weight class. The lightest and heaviest weight classes are assigned similar equity ratios, with slightly lower revenue-to-cost responsibility ratios projected by the Simplified Model than by the ADOT HCAS model in the latter case. These results are reversed for intermediate weight classes, with far higher equity ratios forecast by the Simplified Model than by the ADOT HCAS model. This disparity is most likely produced by two factors: different assessments of the impact of reduced-fee status on revenues generated by these vehicles, and the Simplified Model's distribution of certain construction costs (e.g. bridges) in broader categories with fewer assumptions.

Table 45: Comparison Ratios, Simplified Model to ADOT HCAS Results

Weight Class	Equity Ratios		Equity Comparison[1]
	Simplified Model	ADOT HCAS Model	
0-10,000 lb.	139%	139%	100%
10,000-20,000 lb.	234%	106%	221%
20,000-40,000 lb.	211%	95%	223%
40,000-60,000 lb.	138%	101%	137%
60,000-75,000 lb.	128%	123%	104%
75,000-80,000+ lb.	68%	87%	77%
Total	120%	120%	100%

Note: 1. Simplified Model equity ratio divided by the ADOT HCAS model equity ratio.

Both the more complex ADOT HCAS model and the Simplified Model tell the same basic story. Lighter vehicles are paying more than their cost responsibility. Heavier vehicles are paying less than their cost responsibility. This suggests that if highway finance is to be made more equitable, the relative tax burden should be shifted toward heavier vehicles.

VI. Recommendations & Future Needs

Greater coordination of construction program reporting with the reporting format for either the Federal Model or the ADOT model should be a priority if either of these models are to be used in the future. This could be accomplished through an automated sorting system (e.g. Excel lookup references) or through a reclassification of the construction program categories. However, in light of the fact that two of the three spreadsheets required for updating the current HCAS model are no longer available to ADOT, the functionality of the current model is impeded by a high risk of error inherent in the multiple-step update process. While the Federal Model might be a more efficient and user-friendly interface for conducting future studies, it is not usable as provided.

The Simplified Model developed above provides a useful tool for estimation of equity that can be updated with fewer steps than those required for the ADOT HCAS update. Furthermore, while some degree of variance exists between the results produced by the Simplified Model and the ADOT HCAS for specific vehicle or weight classes and among different weight classes, the variation tends to be concentrated in the least consequential weight classes (from the standpoint of both revenue generation and cost responsibility). In the aggregate, ratios of revenue to cost responsibility produced by the Simplified Model are similar to the results of the ADOT HCAS, with the exception of single unit trucks.

Not only does the Simplified Model provide a reasonable approximation of the results of the ADOT HCAS model with fewer steps and enhanced portability, the Simplified Model is also more accessible for future updates and changes to tax rates, fee structures, etc. The Simplified Model is contained within three linked spreadsheet workbooks, all of which are small enough to fit on a floppy disk. All equations and calculations are visible to the operator, and can be modified to suit future changes in spending or taxation. This is an important advantage over the current ADOT HCAS model, in which much of the allocation of costs and revenues is contained within the FORTRAN programs and thus far less accessible to the average user. The difficulties encountered in the scope of this research in allocating motor carrier fees based on a flat fee structure rather than incremental tax rates using the ADOT HCAS model are a case in point.

The Simplified Model provides ADOT and third-party researchers with a cost effective tool that makes the allocation of revenues and expenditures an easier process. While the differential allocation of revenues and costs to single unit trucks does warrant further research that could be pursued for “fine tuning” of the Simplified Model in the future, the Simplified Model “as-is” provides a reasonable allocation of revenue-to-cost responsibility for various vehicle and weight classes that is both theoretically justifiable and far more user-friendly than the current ADOT HCAS model. The Simplified Model can be easily modified for more complex or simpler attribution operations, making regular updates far more likely, and as such is recommended for use on a regular basis.

Appendix A: Steps Required to Update the Arizona Cost Allocation Model

Methodology

In order to update the Arizona Highway Cost Allocation Study, it is necessary to modify several files read by the FORTRAN allocation programs. In the original model, these modifications were made via several Lotus 1-2-3 spreadsheets that aggregate similar data sets. Print files read by the FORTRAN programs were then created from the spreadsheets. These three spreadsheets were titled EXPEND (a summary of ADOT's five-year construction program), VMTDATA (vehicle miles of travel by vehicle class and highway functional system) and AZREVIN (user revenues by category for base and forecast periods). However, ADOT has only been provided with the EXPEND worksheet. Subsequent modifications to VMT and revenue forecasts have been entered directly into the print files by hand. Data sources are listed in an appendix to this report.

Updates to Expenditure Data

All expenditure data modifications were done in file EXPEND.WK1. The steps below are listed in two parts. First, the original instructions from the 1993 Arizona HCAS are listed with spreadsheet cell references in line items "a." Second, the most recent update actions taken are reported in line items "b." This format is also used in the "Updates to Vehicle Miles of Travel Forecasts" step that follows.

1. a. Replace all data in the "Five-Year Program Total" in thousands at F187..G245.
   b. Data from the 1999 to 2003 ADOT Construction Program were classified by program type by ADOT staff. These totals were entered in the cells above.

2. a. If new program categories are created, add these values to the appropriate row of the summary table at A254..H275.
   b. No action was taken for this step, as the Construction Program was allocated among existing categories in 1.b.

3. a. Update the "Split of Major Non-Construction Program Categories of ADOT" for the program period at U288..U291 from the operating budget developed by ASD, or accept the old split for FY 1993-1997.
   b. For the initial run the old split was accepted.

4. a. Update the "Discretionary Fund Analysis" for the program period at M328..M335 from ASD.
   b. The Discretionary Fund Analysis was updated for years 1999 to 2003 as specified. Note that federal funds were excluded from the "Available for Construction" category to prevent over-allocation of total federal expenditures (which are based on "Projected Federal Apportionments Under ISTEA," see item 9. Below).

5. a. Update the "Forecast of HURF Distribution" for the program period at F364..K369 from ASD.
   b. The HURF distribution forecast was updated as specified.

6. a. Update the "State Aid to Local Governments from the HURF" for the program period at D405..H406 from ASD.
   b. The forecast of state aid was updated as specified.

7. a. Update "Highway Statistics Data on Local Government Finance" from FHWA in columns F421..H483.
   b. In order to preserve the integrity of the spreadsheet and FORTRAN formulas, the years 1993 to 1995 were used for this portion of the update. Note that only the summary data on receipts and disbursements were adjusted; sub-category (e.g. counties, municipalities) details were not available due to the discontinuation of Highway Statistics tables UF-1,2.

8. a. Update data on "Interest Payments on Bonds" at C501..D505.
   b. This step was completed using forecast interest payments from the HURF and RARF for 1999 to 2003 in the cells specified.

9. a. Update the "Projected Federal Apportionments Under ISTEA" by entering new data from ASD at E518..H522.
   b. These data were updated as specified.

Following the above changes, the updated worksheet was saved as a print file "Expend.prn" to be read by the allocation model. As long as cell dimensions are not changed in EXPEND.WK1, a readable print file can be created directly through Excel by selecting: File>Save As>Save As Type>Formatted Text (space delimited).

Because disaggregated county and municipality-level data were not available in the more recent Federal Highway Statistics on Local Government Finance, a control test was performed to ensure that only the aggregate totals were required for the update. The updated aggregate data were maintained, but county and municipality receipts and disbursements were all set to zero. For the update using revenue controls in the program period, this test was successful. The model returned exactly the same cost and revenue results as with the original (partially modified) EXPEND.PRN file. The same was found for the "Forecast from Base Period" methodology, the results of which are shown in Appendix C. Therefore, it can be assumed that failure to change county and municipality data in the "Highway Statistics on Local Government Finance" portion of EXPEND.PRN will have no effect on the model outcome, so long as the totals for local government receipts are changed.

Updates to Vehicle Miles of Travel Forecasts

A copy of the spreadsheet VMTDATA.WK1 was not available for this update. All recalculations and forecasts were first performed in Excel, with new growth rates based

on more recent VMT data supplied by ADOT. Once the new forecasts were calculated, the updated information was entered by hand in the print file "Vmtdata.prn." Due to the multiple steps now involved in this process, it is anticipated that this and future updates will be more subject to user error. Individual steps undertaken are listed below, with the corresponding instructions for updating VMTDATA.WK1 provided with the original allocation model.

1. a. Enter new HPMS percentages at F519..V519, F524..V524, …, F574..V574.
   b. New percentages of travel by vehicle type and functional class of roadway were entered in a spreadsheet for the years 1992 and 1997. The VMT forecasts below use 1997 as a base year, with annual growth rates calculated individually for each vehicle/road class combination based on the change from 1992 to 1997.

2. a. Enter HPMS annual vehicle miles of travel in millions at X519, X524,…, X574.
   b. AVMT data were entered for 1997. Totals for 1997 were used to forecast traffic in the steps below.

3. a. Review the analysis of forecasts in the large table at A411..K510. The only thing that affects other results are the calculated values of rural and urban growth at J422 (2.04%) and J455 (2.53%).
   b. As noted above, growth rates were calculated individually based upon 1997 percentages of travel by vehicle/road class and rates of change in VMT by vehicle/road class from 1992 to 1997. These new growth rates were applied to the 1997 base year data identified in Step 2.b.

4. a. Insert any updated special classification survey data for Other Freeways and Expressways at D590..S590 as decimal percentages.
   b. No changes were made in this step.

5. a. If you want to update registration data, they can be entered at A253..H335. As an alternate approach , increase all registrations at A253..H335 by the weighted average annual VMT growth rate. The weighted average annual VMT growth rate for the original spreadsheet data is 2.32%.
   b. Registrations were updated using the weighted average VMT growth rate for 1992 to 1997 (3.96%). As an alternate method, registrations could be increased more specifically by using historical changes by vehicle class. These rates of change have been calculated for the 1987 to 1997 period, but were not used in the initial run of the update.

6. a. Combination VMT on Rural Local roads is set equal to 3% of Rural Local VMT at M602..R602. This can be changed to any other percentage or left unrestricted.
   b. Combination VMT on Rural Local roads was left unrestricted in the update, and was forecast as described in Step 3.b.

Updates to Tax Rates, Fees and Revenues

As with the updates to vehicle miles of travel, the original spreadsheet AZREVIN.WK1 was not available for this update. Furthermore, the original documentation package did not provide a concise analysis of steps required to update these fields. However, a number of important changes in Arizona motor vehicle revenue collection have occurred recently, and these are not reflected in the original model. The steps below describe how changes were made to the proper files to update tax rates, fees and total revenues. The associated files are discussed in considerable detail in Chapter 6, "Revenue Attribution Program: AZREV.FOR," of the Arizona HCAS Computer Program Documentation Package. Two series of print files required changes for the current update. The first, files AZVCH90.PRN and AZVCH95.PRN, contain information on vehicle characteristics and tax rates for the five configuration types and 23 registered weight classes. The second series, AZRCON90.PRN and AZRCON95.PRN, contain base period and program period control totals for the 12 types of highway user taxes analyzed by AZREV.FOR.

1. Updates to the vehicle characteristics files required changes in state and federal fuel tax rates, elimination of the mileage-based motor carrier tax, addition of motor carrier fees and increased commercial highway use tax. The state fuel and diesel taxes were increased to 18 cents per gallon, and federal fuel and diesel taxes were increased to 18.4 and 24.4 cents per gallon respectively. Values in the mileage-based "Motor Carrier Tax" columns were replaced with zeroes and use fees were increased based on ADOT's weight schedule. Motor carrier fees were added to the "Registration Fees" column for commercial vehicles (classes 4 and 5) only. Historical growth rates (1988 to 1997) were calculated for vehicle valuations based on the Arizona Motor Vehicle Registration database. These growth rates were used to forecast future vehicle valuations from the original model's 1990 base period.

2. Updates to control totals were calculated using base period 1995 to 1999 in AZRCON90.PRN and forecasts for program period 1999 to 2003 in AZRCON95.PRN. In all state forecasts, the average annual revenues from 1999 to 2003 were used. The forecasts of federal fuel tax collections were estimated from projections of state fuel tax collections, assuming a constant ratio of federal to state fuel tax rates. Federal forecasts of use, sales and tire tax collections were projected from the base period using historical growth rates of these variables. The following Revenue Analysis table lists the control totals used for the current HCAS forecast.

Table 46: FY 1999-2003 Revenue Analysis
Control Totals (millions of dollars) and Adjustment Factors

Type of Tax	Control Total	Control Factor	Special Factor
State gasoline tax	$411.012	1.028	1.000
State special fuel tax	$158.412	1.271	1.000
State motor carrier tax	$46.150	0.000	1.000
State vehicle license fees	$712.768	1.703	1.159
State registration fees	$140.772	0.585	1.000
State other vehicle fees	$36.218	13.762	1.000
State other VMT fees	$0.000	0.000	1.000
State other truck VMT fees	$0.000	0.000	1.000
Federal gasoline tax	$420.147	1.028	1.000
Federal special fuel tax	$214.736	1.271	1.000
Federal use tax	$11.360	0.394	1.000
Federal sales tax	$32.884	0.040	1.159
Federal tire tax	$5.968	0.000	1.000

Although the motor carrier fees are shown in the appropriate row in the table, these fees had to be assigned to the "Other Truck VMT" column in order to be included in the model outputs. This is due to the zero-tax-rate made in Step 1 above, which overrides the control total in the HCAS attribution. In other words, the zeros in the motor carrier tax *rate* column that were inserted to reflect the new flat fee structure were multiplied by the control total, resulting in no allocation of the motor carrier fees. To compensate, these fees were placed in the "Other Truck VMT" portion of the AZRCON95.PRN file for the final cost allocation analysis.[8]

ADOT HCAS Output Tables

The ADOT HCAS model can be used to generate a variety of output tables in addition to the revenue to cost responsibility tables discussed in Section IV. The FORTRAN interface allows the user to specify the output tables for the model to generate. Options include estimates of highway user revenues by type of tax, allocation of expenditures by construction categories and equity of the highway tax structure for varying levels of government. Results can be generated for base and forecast program periods (in this case, 1994 to 1998 and 1999 to 2000 respectively). Revenues can be estimated based on model-generated forecasts or program period control totals. The intermediate output

[8] These fees were added to truck registration fees in AZVCH95.PRN, but assigning the control total similarly would result in a portion of the motor carrier fees being allocated to autos and pick-ups. For this reason, motor carrier fees were assigned to the truck-specific category.

tables are useful for assessing the accuracy and reliability of different forecast methods and of the model as a whole. Tables 1 through 5 for the 1999 to 2003 program period using revenue controls supplied by ADOT are shown below.

Table 1 of the HCAS intermediate outputs estimates highway user revenue by various types of taxes and fees. Revenues for a given tax or fee are allocated both to vehicle classes and weight classes, as shown in the two versions of Table 1. As expected, there is a high correlation between traffic volume, number of registrations and fees collected. Autos make up the majority of registrations and of VMT, and as a result comprise the largest source of revenues for fuel and license taxes. Pick-ups make up the second-greatest number of registrations, and generate a commensurate portion of license tax revenues. Despite a low proportion of registrations, combination trucks generally travel greater distances than other vehicle classes. This, combined with low rates of fuel economy and a surcharge on commercial fuel use, makes these vehicles the second largest source of fuel tax revenue. The registration fee results in Table 1 seem counterintuitive, given that autos and pickups comprise the majority of registrations. However, because additional weight-based fees are included in the registration totals, heavier vehicles are allocated a disproportionately large share of total registration fees. Federal revenues include fuel taxes applicable to all vehicles, and sales, tire and use taxes that apply to commercial trucks.

Table 47: HCAS Table #1 by Vehicle Class
Highway User Revenue By Type Of Tax
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	State Revenue					Total State	Federal Revenue	Total State & Federal
	Fuel Tax	Motor Carrier[1]	License Tax	Regist. Fees	Other			
Autos	253,554	-	473,748	8,969	26,184	762,455	259,189	1,021,644
Pick-ups	122,296	-	192,315	3,996	9,317	327,924	125,014	452,938
Buses	3,870	-	1,327	193	17	5,406	4,512	9,918
SU	54,655	-	30,496	7,707	14,860	107,718	74,246	181,963
CB	135,051	-	14,883	119,907	31,989	301,830	222,134	523,964
Total	569,425	-	712,768	140,772	82,368	1,505,332	685,095	2,190,427

Note: 1. Motor Carrier fees are included as "Other Truck VMT" fees (see page 38).

Weight-based revenue allocations are similar to those based on vehicle classes, with the lightest weight category (autos and pick-ups/SUVs) accounting for the majority of state fuel and license tax revenues. The heaviest weight class, made up primarily of combination trucks, accounts for the second-largest portion of state fuel tax revenues and the largest portion of state registration revenues (including weight fees). The impact of added weight-based registration fees can be discerned from the table below. Whereas the lightest weight class accounts for 66 percent of fuel tax revenues and over 93 percent of

license tax revenues, this weight class generates only 9 percent of registration and weight revenues. In contrast, the heaviest weight class generates 21 percent of fuel tax revenues and a mere 2 percent of license tax revenues, but is responsible for over 73 percent of registration and weight fees.

Table 48: HCAS Table #1 by Weight Class
Highway User Revenue By Type Of Tax
For average year during the period FY 1999-2003 (Thousands of Dollars)

Weight Class (000 lb.)	State Revenue					Total State	Federal Revenue	Total State & Federal
	Fuel Tax	Motor Carrier[1]	License Tax	Regist. Fees	Other			
0-8	375,741	-	665,867	12,916	35,491	1,090,014	384,092	1,474,106
8-10	14,014	-	5,565	587	4,869	25,036	14,807	39,843
10-12	4,987	-	2,191	295	1,548	9,021	5,339	14,360
12-14	1,399	-	766	225	376	2,766	1,512	4,277
14-16	2,624	-	1,263	361	741	4,988	2,890	7,878
16-18	2,112	-	1,043	320	552	4,026	2,357	6,384
18-20	3,744	-	1,969	601	991	7,305	4,243	11,548
20-22	1,308	-	632	245	299	2,483	1,501	3,985
22-24	2,122	-	1,110	392	495	4,120	2,472	6,592
24-26	6,650	-	3,739	1,358	1,616	13,362	7,865	21,227
26-28	1,733	-	713	421	330	3,196	2,084	5,280
28-30	1,724	-	877	477	357	3,434	2,106	5,541
30-32	1,226	-	638	461	281	2,605	1,522	4,127
32-36	2,602	-	1,038	1,227	550	5,416	3,972	9,388
36-40	2,447	-	881	1,280	474	5,081	3,720	8,801
40-45	1,537	-	674	934	353	3,498	2,539	6,037
45-50	4,650	-	1,931	3,132	1,103	10,815	7,807	18,623
50-55	7,245	-	3,577	3,762	1,596	16,180	12,800	28,980
55-60	2,891	-	1,070	1,849	657	6,468	5,033	11,501
60-65	3,280	-	1,274	2,063	721	7,338	5,864	13,202
65-70	2,375	-	736	1,559	528	5,199	4,204	9,403
70-75	4,556	-	1,782	2,729	954	10,021	8,352	18,374
75-80	118,459	-	13,433	103,578	27,488	262,957	198,015	460,972
Total	569,425	-	712,768	140,772	82,368	1,505,332	685,095	2,190,427

Note: 1. Motor Carrier fees are included as "Other Truck VMT" fees (see page 38).

Table 2 of the ADOT HCAS output is an expanded version of the revenue and cost responsibility tables discussed in Section IV above, but presents only data for State and State-Aid programs. The expanded table includes an adjusted revenue-to-cost responsibility column that scales aggregate results to a 100 percent benchmark, as well as cost responsibility and revenue generated per mile of travel for each vehicle and weight class. On average, travel by all vehicle classes on state highways will cost about 2.23 cents per vehicle mile over the 1999 to 2003 period. In contrast, the average revenue collected by the state is estimated to be 2.26 cents per vehicle mile of travel. Both costs and revenues per mile of travel increase as vehicles increase in weight, from autos to combination trucks. However, per-mile costs and revenues increase at different rates depending on type of vehicle, operating weight and tax status.

Revenue per mile for pick-ups/SUVs is greater than that for autos because of differences in fuel economy. On a per-mile basis, single unit truck revenues are projected to be 63 percent higher than those of autos and combination truck revenues are projected to be 259 percent greater than those of autos. Bus revenues are only 18 percent greater than autos revenues on a projected per-mile basis and are lower than pick-up revenues. This is due to the tax status of most buses, which are usually owned or leased by government and non-profit organizations and therefore have reduced highway user fees.

Cost responsibility per mile of travel increases far more rapidly than revenues for heavier vehicle classes. The cost responsibility of buses is more than double that of cars, and single unit and combination trucks are expected to have cost responsibilities that exceed those of autos by 282 percent and 422 percent respectively. Pick-ups trucks, while generating 32 percent more revenues than cars on a per-mile basis, do not impose an appreciably greater cost per mile of travel on the highway system. In summation, autos and pick-ups/SUVs are projected to subsidize state highway use by other vehicle classes over the 1999 to 2003 forecast period.

Table 49: HCAS Table #2 by Vehicle Class
Vehicle Miles, Revenue, And Cost Responsibility
For average year during the period FY 1999-2003 (Arizona State Revenue Only)

Vehicle Class	Veh. Miles (Mill.)	User Revenue (Thous.)	Cost Respon. Fed. Meth. (Thous.)	Revenue to Cost Responsibility Ratio		Cost Per Mile (Cents)	Revenue Per Mile (Cents)
				Unadj.	Adj.		
Autos	41,868.7	762,455.2	540,093.1	1.4117	1.0771	1.2900	1.8211
Pick-ups	13,670.9	327,923.7	178,545.0	1.8366	1.4013	1.3060	2.3987
Buses	251.6	5,405.8	6,447.2	0.8385	0.6397	2.5630	2.1490
SU	3,632.6	107,717.7	125,499.5	0.8583	0.6549	3.4549	2.9653
CB	6,398.0	301,829.8	297,935.5	1.0131	0.7729	4.6567	4.7176
Total	65,821.7	1,505,332.2	1,148,520.3	1.3107	1.0000	1.7449	2.2870

Differences in revenue generation and cost responsibility per vehicle mile of travel are shown by weight class in the following table. As indicated above, lighter (non-commercial) traffic appears to be subsidizing highway use by heavier vehicles in the forecast period. The extent of this subsidy generally rises with the weight of subsidized vehicles, beginning most noticeably at the 26,000 to 28,000-pound weight class. It is interesting to note that this weight class was the lowest subject to Arizona's weight-distance tax, which has been replaced with a flat weight fee for the 1999 to 2003 program period. Given the reversal of the trend toward more equitable revenue to cost responsibility for heavier vehicles established in prior updates of Arizona's HCAS, it appears that the change from a weight-distance tax to a flat fee has led to a more inequitable scenario in the current forecast.

Table 50: HCAS Table #2 by Wt. Class: Vehicle Mi., Revenue, & Cost Responsibility For average year during the period FY 1999-2003 (Arizona State Revenue Only)

Weight Class (000 lb.)	Veh. Miles (Mill.)	User Revenue (Thous.)	Cost Respon. Fed. Meth. (Thous.)	Revenue to Cost Responsibility Ratio		Cost Per Mile (Cents)	Revenue Per Mile (Cents)
				Unadj.	Adj.		
0-8	55,524.4	1,090,014.3	718,435.4	1.5172	1.1576	1.2939	1.9631
8-10	1,203.9	25,036.0	26,368.0	0.9495	0.7244	2.1903	2.0796
10-12	399.9	9,021.3	9,159.8	0.9849	0.7514	2.2906	2.2559
12-14	111.6	2,765.5	2,336.0	1.1838	0.9032	2.0925	2.4772
14-16	189.8	4,988.4	4,884.2	1.0213	0.7792	2.5740	2.6289
16-18	146.4	4,026.4	3,738.9	1.0769	0.8216	2.5532	2.7495
18-20	251.3	7,304.8	6,654.1	1.0978	0.8376	2.6474	2.9062
20-22	84.4	2,483.4	2,248.0	1.1047	0.8429	2.6623	2.9411
22-24	133.9	4,120.0	4,024.9	1.0236	0.7810	3.0064	3.0775
24-26	408.8	13,362.3	12,822.4	1.0421	0.7951	3.1367	3.2688
26-28	103.4	3,196.5	3,422.4	0.9340	0.7126	3.3085	3.0901
28-30	101.0	3,434.5	4,513.3	0.7610	0.5806	4.4689	3.4007
30-32	70.2	2,605.2	3,181.9	0.8188	0.6247	4.5343	3.7125
32-36	143.4	5,416.1	6,546.1	0.8274	0.6313	4.5650	3.7770
36-40	131.2	5,081.0	4,631.3	1.0971	0.8371	3.5287	3.8714
40-45	80.5	3,498.2	3,109.3	1.1251	0.8584	3.8626	4.3457
45-50	237.7	10,815.4	11,376.1	0.9507	0.7254	4.7866	4.5507
50-55	359.2	16,179.7	16,934.7	0.9554	0.7290	4.7147	4.5045
55-60	140.9	6,468.0	5,841.1	1.1073	0.8449	4.1441	4.5889
60-65	156.1	7,337.7	6,179.7	1.1874	0.9059	3.9576	4.6992
65-70	111.7	5,199.2	3,978.1	1.3070	0.9972	3.5601	4.6529
70-75	208.0	10,021.4	8,624.8	1.1619	0.8865	4.1466	4.8180
75-80	5,523.8	262,956.9	279,509.7	0.9408	0.7178	5.0601	4.7604
Total	65,821.7	1,505,332.2	1,148,520.3	1.3107	1.0000	1.7449	2.2870

Table 3 allocates state expenditures to vehicle classes by type of expenditure, including a more detailed breakdown of construction costs. Table 3 also presents an allocation of cost responsibility borne solely by vehicles paying all fees assessed by the state, which excludes government and certain reduced-fee vehicles (e.g. agricultural vehicles). Sub-categories of spending in Table 3 are applicable to direct expenditures made by the state. Expenditures made by local governments using financial aid provided by the state have not been allocated to more specific categories, and appear as "Total State-Aid" expenditures in Table 3.

Pavement rehabilitation, new pavement construction and bridge replacement costs are mostly allocated to heavier vehicles. Combination trucks have been assigned 67.8 percent of responsibility for pavement rehabilitation costs, 54.4 percent of new pavement construction costs, and 43.6 percent of bridge replacement costs in the 1999 to 2003 forecast. Forecast ratios of cost responsibility of single unit trucks for these categories are 12.6 percent, 14.3 percent and 15.3 percent respectively. The largest share of construction expenditures assigned to single unit trucks is for new bridge construction, 18.1 percent. Autos and pick-ups made up the majority of cost responsibility allocated for new bridge construction, bridge repair and other construction, though in all cases their allocated responsibility was not as great as the share of travel allocated to these vehicles.

The proportional representation of "Pavement Rehab" expenditures in the forecast period is much greater than that of the original HCAS. This results in a greater construction cost responsibility being assigned to heavier vehicles. As discussed on page 21, it is possible that different methods of assigning Obligation Program expenditures in the current and the 1993 update are responsible for the shift in proportional representation of Pavement Rehabilitation costs.

Table 51: HCAS Table #3 by Vehicle Class
Arizona Direct State Expenditures By Construction Category - Federal Method
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	Construction Category						Total Constr.
	New Pavement	Pavement Rehab.	New Bridge	Replace Bridge	Repair Bridge	Other Const.	
Autos	7,006	14,044	3,669	7,813	5,523	75,470	113,525
Pick-ups	2,206	4,490	1,379	2,635	1,689	23,636	36,035
Buses	184	540	52	461	103	794	2,135
SU	4,300	12,315	1,657	4,066	963	9,582	32,884
CB	16,354	66,056	2,383	11,581	1,740	20,122	118,236
Total	30,051	97,444	9,140	26,556	10,019	129,604	302,815

Common or "configuration neutral" costs such as Highway Patrol, Other Arizona DOT, etc. appear in similar ratios as found in the original Arizona HCAS. Note however that combination VMT have increased proportionally to other vehicles in the latest update, which has led to an increased percentage of cost responsibility for common costs being borne by combination trucks.

The distribution of total cost responsibility for State and State-Aid expenditures has shifted from lighter to heavier vehicles between the 1993 to 1997 allocation period and the current 1999 to 2003 forecast. Rising share of total VMT attributable to trucks, as well as the shifting proportions of construction spending discussed above, have led to an increase from 27 percent of total cost responsibility assigned to single unit and combination trucks in the 1993 to 1997 allocation to an attribution of greater than 40 percent for the 1999 to 2003 period. Shares of total responsibility for State and State-Aid expenditures decreased from 50 percent to 45 percent for autos and from 23 percent to 15 percent for pick-ups over the two study periods. Cost responsibility allocated to buses was the least changed between the two periods, remaining just below 1 percent.

Table 51: HCAS Table #3 by Vehicle Class(CONTINUED)
Arizona Expenditures For State Program - Federal Method
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	Maint.	Other Az. DOT	Highway Patrol	Total Direct State	Total State-Aid	Total Direct St. & St.-Aid
Autos	57,335	102,342	24,439	297,641	242,452	540,093
Pick-ups	17,793	33,334	7,469	94,631	83,914	178,545
Buses	419	1,318	189	4,061	2,386	6,447
SU	4,343	24,020	1,818	63,065	62,435	125,500
CB	10,642	67,051	4,142	200,071	97,865	297,936
Total	90,532	228,065	38,056	659,468	489,053	1,148,520

The allocation of responsibility for expenditures attributed to full-fee paying vehicles was also changed from the 1993 to 1997 forecast period based on adjustments in the spending program and proportional shares of travel by vehicle class. However, it should be noted that the database of registrations by weight has not been updated since the original Arizona HCAS. Therefore, disproportionate changes to traffic may have a magnified effect based on the old distributions of reduced-fee vehicle registrations.

The allocation of cost responsibility to full-fee paying vehicles reduces total construction cost responsibility by $16.0 million over the 1999 to 2003 forecast period. In other words, vehicles with reduced fees have been assigned responsibility for 5.3 percent of construction expenditures. For all State and State-Aid expenditures, the attribution of costs to full-fee paying vehicles is $1,083 million, or $65.0 million below total cost responsibility of all vehicles. The costs allocated to full-fee paying vehicles reflect the

degree to which tax status can affect certain vehicle classes, illustrating the relative frequency of reduced-fee vehicles in a given class.

The reduced fee status of various vehicles classes can be inferred from the two renditions of Table 3 by dividing the difference between the total and full-fee allocations by the total allocation for each vehicle class. For example, in the 1999 to 2003 forecast, buses are allocated $6.4 million in total cost responsibility for all vehicles versus $863 thousand in total cost responsibility for full-fee paying vehicles. The difference between the two allocations is $5.5 million, roughly 87 percent of the total allocation to all vehicles. This implies that 87 percent of buses are reduced-fee vehicles.[9] The ratios of reduced-fee vehicles to total vehicles calculated via this assumption for other vehicle classes are 3.3 percent for autos, 6.5 percent for pick-ups, 22.1 percent for single unit trucks and 0.7 percent for combination trucks. This has affected the distribution of cost responsibility among full-fee paying vehicles, particularly for combination trucks, which bear a greater proportion of responsibility for construction costs allocated to full-fee vehicles in the 1999 to 2003 period.

Table 52: HCAS Table #3 by Vehicle Class (Full Fee)
Arizona Direct State Expenditures For Full Fee Paying Vehicles
By Construction Category - Federal Method
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	Construction Category						Total Constr.
	New Pavement	Pavement Rehab.	New Bridge	Replace Bridge	Repair Bridge	Other Const.	
Autos	6,773	13,576	3,547	7,552	5,339	72,956	109,743
Pick-ups	2,063	4,198	1,290	2,463	1,579	22,100	33,694
Buses	25	72	7	61	14	107	285
SU	3,354	9,610	1,290	3,167	749	7,451	25,620
CB	16,246	65,620	2,367	11,503	1,728	19,986	117,450
Total	28,461	93,076	8,500	24,747	9,410	122,600	286,792

As in the allocation of cost responsibility to all vehicles, allocation to full-fee vehicles has exhibited a trend toward greater cost responsibility on the part of trucks in the 1999 to 2003 forecast period. Total responsibility for State and State-Aid expenditures for full-fee paying autos declined from 51 percent in the 1993 to 1997 forecast to 46 percent in the current forecast. Full-fee pick-ups have been allocated 15 percent of cost responsibility in the current period, down from 22 percent from 1993 to 1997. The shares allocated to full-fee trucks rose from 22 percent to 30 percent for combinations and nearly doubled from 5 percent to 9 percent for single unit trucks.

[9] This method of deriving fee status by vehicle class assumes equal distributions of travel among vehicles of a given class, regardless of tax status.

Table 52: HCAS Table #3 by Vehicle Class (Full Fee)(CONTINUED)
Arizona Expenditures For State Program - Federal Method For Full Fee Paying Vehicles
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	Maint.	Other Az. DOT	Highway Patrol	Total Direct State	Total State-Aid	Total Direct St. & St.-Aid
Autos	55,426	98,933	23,625	287,727	234,376	522,103
Pick-ups	16,636	31,168	6,984	88,482	78,462	166,943
Buses	56	176	25	543	320	863
SU	3,377	18,704	1,413	49,114	48,584	97,698
CB	10,569	66,603	4,114	198,736	97,219	295,955
Total	86,064	215,585	36,160	624,602	458,961	1,083,563

HCAS Table 4 provides estimates of cost responsibility attributable to various vehicle and weight classes in the forecast period based on different sources of funding used for highway expenditures. For the 1999 to 2003 forecast, Direct State expenditures make up the largest total amount of costs allocated to the various vehicle and weight classes, averaging $659.5 million annually. Federal expenditures are projected to average $529.3 million annually, slightly less than projected Direct State expenditures. However, when State-Aid to Local Governments is considered, total cost responsibility for *all* state-funded programs is over twice as high as federally-funded programs over the forecast period. "Other Local" expenditures (i.e. non-state or federally-funded) comprise a relatively small portion of total cost responsibility, averaging $146.6 million annually.

Cost responsibility is distributed differently among vehicle classes depending on the funding source of a given program. These differences are likely a reflection of variance in types of projects funded and the allocation of revenues to alternate priorities at different levels of spending. State and State-Aid expenditures are more highly allocated to autos than are expenditures made via other funding sources. Cost responsibility for autos is forecast to be 47 percent of State and State-Aid expenditures for fiscal 1999 to 2003, but this responsibility drops to 43 percent when all funding sources are considered. Combination trucks bear the brunt of this reallocation of cost responsibility, with a 26 percent responsibility for State and State-Aid expenditures rising to 31 percent when all funding sources are considered. As indicated in the table below, federally-funded projects tend to be allocated mostly to trucks, in contrast with projects funded at other levels of government.

The latest forecast period also represents a reallocation of responsibility from lighter to heavier vehicles in comparison with the 1993 to 1997 cost allocation. For state-funded programs, cost responsibility of autos dropped from 50 percent to 47 percent of expenditures between the 1993 to 1997 forecast and the 1999 to 2003 forecast. Pick-ups/SUVs had a similar decline, from 23 percent to 15 percent. The cost responsibility of

single unit trucks increased from 6 percent to 11 percent of state-funded programs, while combinations rose from 21 percent to 26 percent. Results are similar when all levels of spending are considered: cost responsibility of autos and pick-ups respectively declined from 47 percent and 22 percent of total spending from 1993 to 1997 to 43 percent and 14 percent of expenditures in the 1999 to 2003 forecast. Single unit trucks' cost responsibility increased from 6 percent to 11 percent of all levels of highway spending, while combination trucks were assigned 31 percent of total expenditures for the 1999 to 2003 forecast, versus 25 percent of 1993 to 1997 program expenditures.

Table 53: HCAS Table #4 by Vehicle Class
Cost Responsibility Broken Down By Source Of Funds - Fed. Method
For average year during the period FY 1999-2003 (Thousands of Dollars)

Vehicle Class	Direct State	State-Aid	Other Local	Federal-Aid	Total
Autos	297,641	242,452	70,503	177,297	787,892
Pick-ups	94,631	83,914	23,262	58,151	259,957
Buses	4,061	2,386	660	3,860	10,967
SU	63,065	62,435	16,886	59,747	202,133
CB	200,071	97,865	35,240	230,199	563,374
Total	659,468	489,053	146,551	529,254	1,824,325

As shown in the weight-based allocation below, total cost responsibility for expenditures funded at all levels of government is generally concentrated in the lightest weight class (0 to 8,000 pounds) and the heaviest (75,000 pounds and above). Together these two weight classes have been allocated responsibility for 87 percent of state-funded expenditures and 88 percent of all highway expenditures. However, the responsibility allocated to the lightest weight class has declined significantly since the 1993 to 1997 allocation, to such an extent that the collective responsibility of the two weight classes mentioned above has fallen from 92 percent of both state-funded expenditures and all highway expenditures. Cost responsibility of other weight classes has changed accordingly, with vehicles weighing between 8,000 pounds and 12,000 in the current forecast receiving roughly twice the percentage of costs allocated to these weight classes in the prior cost allocation period.

As mentioned in the discussion of cost responsibility by vehicle class and source of funds, the cost responsibility allocated to different weight classes varies by funding source. Distribution of responsibility for federally-funded projects tends toward the heaviest vehicles to a much greater extent than other levels of funding. At the opposite end of the spectrum, cost responsibility for local projects (both State-Aid and Other Local) tends to fall on the lightest vehicles in the greatest proportion. Local expenditures are generally more highly geared toward traffic safety and general maintenance and administration, which are common costs allocated by share of VMT. Heavier

construction common to the Direct State and Federal-Aid funding sources tends to be allocated in larger proportions based on ESALs and operating weight, which assigns greater cost responsibility to heavier vehicles for projects funded at these levels. Cost responsibilities by weight class for various levels of highway funding are shown in the table below.

Table 54: HCAS Table #4 by Weight Class
Cost Responsibility Broken Down By Source Of Funds - Fed. Method
For average year during the period FY 1999-2003 (Thousands of Dollars)

Weight Class	Direct State	State-Aid	Other Local	Federal-Aid	Total
0-8	392,161	326,274	93,738	235,377	1,047,551
8-10	13,325	13,043	3,171	10,700	40,239
10-12	4,637	4,522	1,123	3,869	14,152
12-14	1,240	1,096	275	1,019	3,630
14-16	2,416	2,469	632	2,173	7,690
16-18	1,886	1,853	473	1,697	5,909
18-20	3,327	3,327	850	3,058	10,562
20-22	1,169	1,079	282	1,094	3,624
22-24	1,997	2,028	542	1,937	6,504
24-26	6,260	6,563	1,763	6,155	20,740
26-28	1,808	1,615	450	1,804	5,676
28-30	2,257	2,256	656	2,358	7,527
30-32	1,594	1,588	462	1,679	5,323
32-36	3,406	3,140	938	3,580	11,064
36-40	2,733	1,898	558	2,809	7,998
40-45	1,913	1,196	353	1,939	5,401
45-50	6,639	4,737	1,473	7,023	19,872
50-55	10,049	6,886	2,064	10,176	29,174
55-60	3,432	2,409	739	3,662	10,242
60-65	3,921	2,259	683	4,034	10,897
65-70	2,554	1,424	435	2,732	7,145
70-75	5,195	3,430	1,055	5,623	15,304
75-80	185,548	93,962	33,838	214,756	528,103
Total	659,468	489,053	146,551	529,254	1,824,325

As indicated in Table 4, "Other Local" and "Federal" expenditures comprise a significant portion of total highway expenditures in Arizona. The original HCAS documentation discusses a "broad case" cost allocation scenario in which these additional expenditures, as well as revenues collected by local and federal entities, are factored into the overall allocation. While the original documentation does not include the "broad case" scenario for the *state* cost allocation because it includes variance of revenues and expenditures outside of direct state control, the broad case has been used for subsequent updates of the Arizona HCAS. This has been done because consideration of equity at other levels of funding can be useful for assessing potential "carry-over" impacts (i.e. shifts in funding or costs from one level to another) on the state system. These various equity scenarios have been discussed in the HCAS results in Section IV, and are shown in greater detail in Table 5.

Table 5 presents a ratio comparison of cost responsibility and revenue generation by vehicle and weight class for different levels of government as shown in Tables 3 and 4. In the aggregate, the "State, State-Aid and Other Local" revenue-to-cost responsibility ratio is projected to be the most equitable (as measured by deviation from a ratio of 1.00) over the 1999 to 2003 forecast period. The subtraction of "Other Local" revenues and expenditures from this baseline reduces equity in the aggregate, and shifts the overall revenue-to-cost responsibility substantially, from 16 percent overpayment (ratio of 1.16) to 31 percent overpayment in the program period. Similar results are obtained when "Federal" revenues and expenditures are combined with the "State and State-Aid" baseline, though in this case, inequity is reduced slightly. Inequity is reduced when all levels of government are combined in the "broad case" scenario as discussed above. The overall revenue-to-cost responsibility ratio in the broad case is 1.20, or 20 percent overpayment in the aggregate.

Just as in the case of the "State, State-Aid and Local" baseline, equity varies considerably among vehicle classes in the various scenarios shown in Table 5. For example, the subtraction of "Other Local" funding elevates the revenue-to-cost responsibility ratio of pick-ups from 1.62 to 1.84, whereas substitution of "Federal" funding increases the ratio of pick-ups to an even greater extent (1.91). In contrast, inclusion of either of these additional funding sources has virtually the same effect on autos. This is likely due to the different sources of revenues at various levels of government. Federal highway revenues are mostly attributable to fuel taxes, so the less-efficient fuel economy of pick-ups (relative to autos) results in a greater proportion of federal revenues, maintaining a higher level of revenues to cost responsibility than local (non-fuel) taxes.

Table 55: HCAS Table #5 by Vehicle Class
Equity Of Arizona Highway Tax Structure By Different Levels Of Government
For Average Year During The Period FY 1999-2003 - Fed. Method

Vehicle Class	Revenue-to-Cost Responsibility Ratios				
	State & State-Aid		State, State-Aid & Other Local	State, State-Aid & Fed.	State, State-Aid, Other Local & Fed.
	Unadjusted	Adjusted			
Autos	1.4117	1.0771	1.2487	1.4241	1.2967
Pick-ups	1.8366	1.4013	1.6249	1.9136	1.7424
Buses	0.8385	0.6397	0.7606	0.9622	0.9043
SU	0.8583	0.6549	0.7565	0.9823	0.9002
CB	1.0131	0.7729	0.9059	0.9921	0.9300
Total	1.3107	1.0000	1.1624	1.3056	1.2007

Relative to the "State, State-Aid and Local" funding baseline, other disparities exist at different funding levels among vehicle and weight classes. The revenue-to-cost responsibility ratios of most vehicle classes increase when either local or federal funding sources are excluded or substituted in the allocation. This is especially evident in the case of single unit trucks, which experience a significant rise in revenue-to-cost responsibility when federal funding sources are included. Revenue-to cost responsibility is increased for all vehicle classes in the "broad case" scenario. Both autos and pick-ups/SUVs are projected to be overpaying at all levels of analysis.

The weight-based equity ratios for various funding scenarios are virtually identical to the ratios by vehicle class shown above. The two lightest weight classes, "0 to 8,000 lb." and "8,000 to 10,000 lb.," are projected to be overpaying in every scenario for the 1999 to 2003 program period, whereas all other weight classes generally demonstrate fluctuations between levels of overpayment and underpayment. The inclusion of local funding tends to reduce overpayment by most weight classes to a greater extent than the inclusion of federal funding, with the exception of the heaviest weight class and several intermediate classes (e.g. 14,000 to 16,000 pounds). In the case of single unit trucks, which make up the majority of vehicles registered in the "8,000 to 10,000 lb." weight class, lighter trucks appear to be subsidizing heavier vehicles. Equity ratios by source of funds and weight class are shown in further detail in the following table.

Table 56: HCAS Table #5 by Weight Class
Equity Of Arizona Highway Tax Structure By Different Levels Of Government
For Average Year During The Period FY 1999-2003 - Fed. Method

Weight Class	Revenue-to-Cost Responsibility Ratios				
	State & State-Aid		State, State-Aid & Other Local	State, State-Aid & Fed.	State, State-Aid, Other Local & Fed.
	Unadjusted	Adjusted			
0-8	1.4719	1.1230	1.3020	1.4934	1.3598
8-10	1.7225	1.3142	1.5257	1.8000	1.6415
10-12	0.9244	0.7053	0.8296	1.0404	0.9665
12-14	0.8643	0.6594	0.7620	0.9875	0.9051
14-16	1.0132	0.7730	0.9059	0.9937	0.9313
16-18	1.3099	0.9994	1.1617	1.3051	1.2003
18-20	1.0978	0.8376	0.9734	1.1890	1.0934
20-22	1.1047	0.8429	0.9818	1.1923	1.0997
22-24	1.0236	0.7810	0.9022	1.1058	1.0136
24-26	1.0421	0.7951	0.9162	1.1186	1.0235
26-28	0.9340	0.7126	0.8256	1.0103	0.9303
28-30	0.7610	0.5806	0.6645	0.8063	0.7361
30-32	0.8188	0.6247	0.7149	0.8490	0.7753
32-36	0.8274	0.6313	0.7237	0.9271	0.8486
36-40	1.0971	0.8371	0.9792	1.1829	1.1004
40-45	1.1251	0.8584	1.0104	1.1958	1.1177
45-50	0.9507	0.7254	0.8417	1.0122	0.9371
50-55	0.9554	0.7290	0.8516	1.0689	0.9933
55-60	1.1073	0.8449	0.9830	1.2102	1.1229
60-65	1.1874	0.9059	1.0692	1.2926	1.2116
65-70	1.3070	0.9972	1.1781	1.4013	1.3159
70-75	1.1619	0.8865	1.0352	1.2896	1.2006
75-80	0.9408	0.7178	0.8392	0.9326	0.8729
Total	1.3107	1.0000	1.1624	1.3056	1.2007

Appendix B: References and Data Sources

Most data requirements for the HCAS update were provided by ADOT staff. The following persons are points of contact for data needed in future updates of the cost allocation model. Each listing is followed by phone and fax numbers, an ADOT internal mailing address and an e-mail address. Bullet points beside each name indicate the data sets provided by that individual.

Mark Catchpole (602) 712-8596 Phone (602) 712-4214 Fax Mail Drop 310B mcatchpole@dot.state.az.us	• VMT by roadway and vehicle class • Commercial vehicle characteristics • Functional classification of roadway segments
Arnold Burnham (602) 712- Phone (602) 712- Fax Mail Drop aburnham@dot.state.az.us	• Five-year Construction Program
Nettie Klingler (602) 712-8655 Phone (602) 712-6672 Fax Mail Drop 200B nklingler@dot.state.az.us	• HURF forecast and distribution • Tax rates and fuel gallonage estimates • Vehicle registration database • Commercial/non-commercial revenue attributions
John McGee (602) 712-7441 Phone (602) 712-6672 Fax Mail Drop 200B jmcgee@dot.state.az.us	• Motor carrier fees • Fuel gallonage estimates • Debt service by issue • ADOT Discretionary Fund Analysis
Jess Jarvis (602) 712- Phone (602) 712- Fax Mail Drop 310B jjarvis@dot.state.az.us	• Survey of local expenditures
John Semmens (602) 712-3137 Phone (602) 712-6367 Fax Mail Drop 075R jsemmens@dot.state.az.us	• Classification of construction program expenditures • Federal Highway Statistics on Local Government Finance

Lonnie Hendrix (602)712-7972 Phone (602)712- Fax Mail Drop	• Estimates of maintenance expenditures by pavement and non-pavement categories
Barry Crockett (602)712-8269 Phone (602)712- Fax Mail Drop bcrockett@dot.state.az.us	• Contracts and specifications data for breakdown of specific projects by expenditure category

The following references provide background on the Arizona HCAS model, highway cost allocation in general, and descriptions and forecasts of revenue categories and sources:

1997 Federal Highway Cost Allocation Study, U.S. Department of Transportation, 1997

Arizona Highway Cost Allocation Study: FY 1996 Update, Arizona Department of Transportation, 1996

Arizona Highway Cost Allocation Study, SYDEC, Inc., Cambridge Associates and R.D. Mingo and Associates, 1993

Comprehensive Truck Size and Weight Study, Batelle Team, Federal Highway Administration, 1995

Maricopa County Recommended Tentative Budget: Capital Projects Department Summary, Maricopa County Budget and Finance Department, 1999

Pima County 1997 CAFR, Pima County Department of Finance, 1997

Statistics on Local Government Finance, Federal Highway Administration, 1992 to 1996

Update of Arizona Highway Revenues Review Study, Arizona Department of Transportation, 1998

Appendix C: VMT and ESAL Matrices for the Simplified Cost Allocation Model

Cost allocation by weight class in the Simplified Model is achieved through use of VMT and ESAL factors assigned to weight classes and vehicle configurations. Because VMT are reported by vehicle classes and configuration and not by weight, it was necessary to split the aggregate VMT data into weight classes using registration data supplied with the ADOT HCAS. Proportions of rural, urban and total VMT for each vehicle class and/or configuration were multiplied by the percentage of vehicles registered in each weight category to determine the proportion of travel attributable to vehicles of a given weight class. The proportional representation of vehicle and weight classes in the 1990 registration report produced for the original ADOT HCAS are shown below.

Table 57: Vehicle Registrations

Weight Class	Proportion of All Registrations, 1990					
	Autos	Pick-ups	Buses	Single Units	Comb.	Total
0-8,000 lb.	0.7145	0.2583	0.0000	0.0000	0.0000	0.9728
8,000-10,000 lb.	0.0000	0.0000	0.0003	0.0077	0.0000	0.0081
10,000-12,000 lb.	0.0000	0.0000	0.0003	0.0024	0.0000	0.0027
12,000-14,000 lb.	0.0002	0.0001	0.0001	0.0005	0.0000	0.0009
14,000-16,000 lb.	0.0000	0.0000	0.0001	0.0011	0.0000	0.0012
16,000-18,000 lb.	0.0000	0.0000	0.0002	0.0008	0.0000	0.0010
18,000-20,000 lb.	0.0000	0.0000	0.0002	0.0014	0.0000	0.0016
20,000-22,000 lb.	0.0000	0.0000	0.0002	0.0004	0.0000	0.0005
22,000-24,000 lb.	0.0000	0.0000	0.0002	0.0006	0.0000	0.0008
24,000-26,000 lb.	0.0000	0.0000	0.0002	0.0020	0.0001	0.0023
26,000-28,000 lb.	0.0000	0.0000	0.0003	0.0003	0.0000	0.0006
28,000-30,000 lb.	0.0000	0.0000	0.0002	0.0004	0.0000	0.0006
30,000-32,000 lb.	0.0000	0.0000	0.0000	0.0003	0.0000	0.0003
32,000-36,000 lb.	0.0000	0.0000	0.0002	0.0004	0.0000	0.0006
36,000-40,000 lb.	0.0000	0.0000	0.0002	0.0002	0.0001	0.0005
40,000-45,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0001	0.0002
45,000-50,000 lb.	0.0000	0.0000	0.0000	0.0003	0.0002	0.0006
50,000-55,000 lb.	0.0000	0.0000	0.0000	0.0007	0.0002	0.0009
55,000-60,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0001	0.0003
60,000-65,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0001	0.0003
65,000-70,000 lb.	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002
70,000-75,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0001	0.0003
75,000-80,000 lb.	0.0000	0.0000	0.0000	0.0003	0.0023	0.0026
Total	0.7147	0.2584	0.0027	0.0206	0.0036	1.0000

Source: "MV_SYDEC.DAT", ADOT HCAS Model, 1993

A configuration matrix for single unit and combination trucks was used to further refine registration data to assign VMT to various combinations of weight class and truck configuration. These figures were also obtained from the ADOT HCAS model. Note that ratios correspond to each vehicle sub-category. For example, 3-axle single unit trucks with registered gross weight of 45,000 to 50,000 pounds make up 3.5 percent of *single unit truck* configurations, not 3.5 percent of all truck configurations. Thus the column totals below add to 100 percent for each of the three sub-categories.

Table 58: Ratios of Truck Configuration by Weight Class

RGW	Single Unit Trucks			Combinations (1 Trailer)				Combinations (2+Trailers)		
	2A6T	3A	4A	3A	4A	5A	6+A	5A	6A	7+A
0-8	0.0701	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8-10	0.1218	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
10-12	0.0492	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
12-14	0.0217	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
14-16	0.0359	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
16-18	0.0484	0.0017	0.0017	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
18-20	0.0492	0.0008	0.0008	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
20-22	0.0225	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
22-24	0.0501	0.0025	0.0025	0.0001	0.0012	0.0000	0.0000	0.0001	0.0001	0.0001
24-26	0.0676	0.0017	0.0017	0.0008	0.0004	0.0000	0.0008	0.0001	0.0001	0.0001
26-28	0.0442	0.0017	0.0017	0.0008	0.0001	0.0000	0.0000	0.0002	0.0002	0.0002
28-30	0.0267	0.0025	0.0025	0.0015	0.0004	0.0000	0.0001	0.0001	0.0001	0.0001
30-32	0.0108	0.0008	0.0008	0.0000	0.0008	0.0000	0.0000	0.0002	0.0002	0.0002
32-36	0.0134	0.0042	0.0042	0.0012	0.0004	0.0004	0.0001	0.0001	0.0001	0.0001
36-40	0.0100	0.0058	0.0058	0.0012	0.0012	0.0001	0.0000	0.0002	0.0002	0.0002
40-45	0.0003	0.0125	0.0125	0.0023	0.0012	0.0015	0.0004	0.0001	0.0001	0.0001
45-50	0.0142	0.0350	0.0350	0.0081	0.0027	0.0019	0.0008	0.0002	0.0002	0.0002
50-55	0.0025	0.0300	0.0300	0.0035	0.0042	0.0008	0.0000	0.0009	0.0009	0.0009
55-60	0.0050	0.0142	0.0142	0.0046	0.0100	0.0035	0.0004	0.0028	0.0028	0.0028
60-65	0.0003	0.0150	0.0150	0.0038	0.0046	0.0031	0.0004	0.0003	0.0002	0.0002
65-70	0.0018	0.0008	0.0008	0.0012	0.0012	0.0023	0.0012	0.0028	0.0028	0.0028
70-75	0.0003	0.0017	0.0017	0.0015	0.0012	0.0410	0.0008	0.0075	0.0104	0.0104
75-80	0.0058	0.0327	0.0327	0.0184	0.0169	0.7763	0.0679	0.2974	0.3227	0.3255
Total	0.6718	0.1641	0.1641	0.0491	0.0464	0.8314	0.0731	0.3136	0.3418	0.3446

Source: "RGW_OGW.DAT", ADOT HCAS Model, 1993

The above matrices were used to assign proportions of VMT by vehicle class and configuration to the various weight classes. For example, rural VMT for 4-axle, 1-trailer combinations was divided by total rural VMT to determine the proportion of rural VMT assigned to this particular truck configuration. In order to find the percentage of rural VMT to assign to 4-axle, 1-trailer combinations with a registered weight of 22,000 to

24,000 pounds, the overall VMT ratio is multiplied by 0.0012 (see Truck Configuration table above). To determine the ratio of urban traffic allocated to buses with registered weight between 26,000 and 28,000 pounds, the percentage of overall urban program-period VMT for buses (0.38 percent) is multiplied by the proportion of bus registrations in this specific weight category (0.0003).

The final matrix of rural VMT ratios by weight class and vehicle type appears on the next page. Similar matrices were created for urban VMT and total VMT. The rural and urban VMT matrices were used to allocate costs in the two basic scenarios of the Simplified Model. "Urban and Common" costs were allocated to each weight class based on the sum of figures in the corresponding row of the Urban VMT matrix. Rural expenditures were allocated using a combination of the final matrix of rural VMT by weight class and vehicle type and a matrix of ESAL factors applicable to each weight/configuration entry. The proportion of rural VMT for each weight/configuration was multiplied by the corresponding ESAL factor to obtain a weighted responsibility. All weighted responsibilities were then scaled to total 100 percent, and the corresponding scaled cost responsibilities were used as allocation factors in the Simplified Model for "rural" weight-based expenditures by vehicle and weight class.

The ESAL factors assigned to each vehicle/weight class combination were derived through a series of steps shown in the tables on pages 74 to 75. Baseline weight distributions for different vehicle classes are shown in the first table. Estimates for autos and pick-ups were made by the researcher for this study, while typical axle weight distribution ratios for various truck configurations were taken from the FHWA *Comprehensive Truck Size and Weight Study* (1995). Buses were assigned a weight distribution identical to that of 3-axle single unit trucks.

The second table on page 74 shows the standard axle loads used to calculate ESALs for all other axle weights. The standard load for single axles is 18,000 pounds. Standardized estimates for paired and triple axles were not available for this study, but were derived algebraically based on ESAL factors reported for various truck configurations in the FHWA study. Double axles were assigned a standard load of 33,275 pounds, and triple axles were assigned a standard load of 47,765 pounds.

The two tables on page 74 were used to calculate the final matrix of ESAL factors as follows: First, a default weight[10] for each weight class was allocated among the axles or axle combinations using the weight distribution ratios in the first table. Each axle weight was then divided by the standard divisor shown in the second table, and then raised to the fourth power to approximate the exponential impact of weight on road wear. The result was an ESAL factor for that specific axle or axle combination. All axles/axle

[10] Default weights assigned were generally the midpoints of each weight class, with the exception of the lightest and heaviest classes. In the former case, a default weight of 3,000 lb. was used for autos and pick-ups and a default weight of 6,000 lb. was used for other vehicle categories. In the heaviest weight class, the default weight was scaled upward to reflect vehicles operating above 80,000 lb. as distributed in the new State HCAS model. The heaviest weight class was assigned a default operating weight of 95,000 lb., a weighted average of the State HCAS model estimates rounded to the nearest thousand.

combinations were then summed to obtain a final ESAL estimate for that vehicle/weight class combination. For example, a bus in the 8,000 to 10,000-pound weight category would be assigned a default weight of 9,000 pounds, split among a single front axle (3,000 lb.) and a paired rear axle combination (6,000 lb.). The front axle load would have an ESAL of: $(3{,}000 \div 18{,}000)^4 = 0.00077$; and the rear axle combination would have an ESAL of: $(6{,}000 \div 33{,}275)^4 = 0.00106$. These figures are then added together to obtain a final ESAL for 8,000 to 10,000 pound buses of 0.0018.

It should be noted that the final ESAL matrix on page 75 includes estimates for unrealistic vehicle/weight combinations. For example, the matrix reports an ESAL factor of 120.4 for autos with registered weights of 75,000 to 80,000 pounds, a vehicle class and weight combination that does not exist in the registration database. However, the ESAL factors are not used alone, but rather in conjunction with traffic data. Because *no* autos are registered between 75,000 and 80,000 pounds, this combination has a VMT allocation of zero. This proportion of total VMT attributed to autos (zero) is multiplied by that vehicle/weight class' ESAL to yield a final cost allocation factor of zero. In itself, the ESAL matrix simply presents factors of the relative pavement wear that any vehicle/weight combination *would* produce if it did exist.

Table 59: Proportion of Rural Traffic by Vehicle Class

Weight Class	Autos	Pick-ups	Buses	Single Unit Trucks			Combination Trucks					
				2A	3A	4+A	4A-1T	5A-1T	6A-1T	5A-2T	6A-2T	7A-2T
0-8,000 lb.	0.4798	0.2210	0.0000	0.0051	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
8,000-10,000 lb.	0.0000	0.0000	0.0007	0.0088	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
10,000-12,000 lb.	0.0000	0.0000	0.0007	0.0036	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
12,000-14,000 lb.	0.0001	0.0001	0.0003	0.0016	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
14,000-16,000 lb.	0.0000	0.0000	0.0003	0.0026	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
16,000-18,000 lb.	0.0000	0.0000	0.0004	0.0035	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
18,000-20,000 lb.	0.0000	0.0000	0.0003	0.0036	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
20,000-22,000 lb.	0.0000	0.0000	0.0003	0.0016	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
22,000-24,000 lb.	0.0000	0.0000	0.0004	0.0036	0.0003	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
24,000-26,000 lb.	0.0000	0.0000	0.0005	0.0049	0.0002	0.0000	0.0006	0.0000	0.0001	0.0000	0.0000	0.0000
26,000-28,000 lb.	0.0000	0.0000	0.0006	0.0032	0.0002	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
28,000-30,000 lb.	0.0000	0.0000	0.0004	0.0019	0.0003	0.0001	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
30,000-32,000 lb.	0.0000	0.0000	0.0001	0.0008	0.0001	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000
32,000-36,000 lb.	0.0000	0.0000	0.0004	0.0010	0.0005	0.0001	0.0006	0.0001	0.0000	0.0000	0.0000	0.0000
36,000-40,000 lb.	0.0000	0.0000	0.0005	0.0007	0.0007	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
40,000-45,000 lb.	0.0000	0.0000	0.0000	0.0000	0.0014	0.0003	0.0018	0.0002	0.0000	0.0000	0.0000	0.0000
45,000-50,000 lb.	0.0000	0.0000	0.0000	0.0010	0.0039	0.0008	0.0041	0.0003	0.0001	0.0000	0.0000	0.0000
50,000-55,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0034	0.0007	0.0065	0.0001	0.0000	0.0000	0.0000	0.0000
55,000-60,000 lb.	0.0000	0.0000	0.0000	0.0004	0.0016	0.0003	0.0153	0.0005	0.0000	0.0001	0.0000	0.0000
60,000-65,000 lb.	0.0000	0.0000	0.0000	0.0000	0.0017	0.0004	0.0070	0.0005	0.0000	0.0000	0.0000	0.0000
65,000-70,000 lb.	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0018	0.0004	0.0001	0.0001	0.0000	0.0000
70,000-75,000 lb.	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0018	0.0063	0.0001	0.0003	0.0001	0.0000
75,000-80,000 lb.	0.0000	0.0000	0.0000	0.0002	0.0037	0.0008	0.0247	0.1184	0.0080	0.0106	0.0039	0.0016
Total	0.4799	0.2211	0.0061	0.0483	0.0184	0.0038	0.0699	0.1268	0.0086	0.0112	0.0042	0.0017

Table 60: Proportion of Vehicle Weight Assigned to Each Axle or Axle Pair

	Autos	Pick-ups	Buses	Single Unit Trucks			Combination Trucks					
				2A	3A	4+A	4A-1T	5A-1T	6A-1T	5A-2T	6A-2T	7A-2T
Axle 1	0.60	0.70	0.33	0.33	0.33	0.29	0.15	0.15	0.14	0.11	0.10	0.09
Axle 2	0.40	0.30	0.67	0.67	0.67	0.71	0.43	0.43	0.39	0.25	0.28	0.31
Axle 3							0.43	0.43	0.48	0.24	0.27	0.30
Axle 4										0.20	0.19	0.18
Axle 5										0.20	0.17	0.15

Source: *Comprehensive Truck Size and Weight Study*, FHWA, 1995

Table 61: Standard ESAL Divisor for Each Axle or Axle Pair

	Autos	Pick-ups	Buses	Single Unit Trucks			Combination Trucks					
				2A	3A	4+A	4A-1T	5A-1T	6A-1T	5A-2T	6A-2T	7A-2T
Axle 1	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Axle 2	18,000	18,000	33,275	18,000	33,275	47,765	18,000	33,275	33,275	18,000	33,275	33,275
Axle 3							33,275	33,275	47,765	18,000	18,000	33,275
Axle 4										18,000	18,000	18,000
Axle 5										18,000	18,000	18,000

Table 62: ESAL Estimate by Vehicle Weight and Configuration

Weight Class	Autos	Pick-ups	Buses	Single Unit Trucks			Combination Trucks					
				2A	3A	4+A	4A-1T	5A-1T	6A-1T	5A-2T	6A-2T	7A-2T
0-8,000 lb.	0.0001	0.0002	0.0004	0.0026	0.0004	0.0001	0.0004	0.0001	0.0000	0.0001	0.0001	0.0000
8,000-10,000 lb.	0.0097	0.0155	0.0018	0.0131	0.0018	0.0007	0.0022	0.0004	0.0002	0.0007	0.0005	0.0002
10,000-12,000 lb.	0.0216	0.0346	0.0041	0.0293	0.0041	0.0017	0.0050	0.0008	0.0005	0.0015	0.0011	0.0004
12,000-14,000 lb.	0.0422	0.0675	0.0080	0.0571	0.0080	0.0032	0.0098	0.0017	0.0009	0.0028	0.0022	0.0008
14,000-16,000 lb.	0.0748	0.1197	0.0141	0.1012	0.0141	0.0057	0.0173	0.0029	0.0016	0.0050	0.0038	0.0014
16,000-18,000 lb.	0.1235	0.1975	0.0233	0.1670	0.0233	0.0095	0.0286	0.0048	0.0026	0.0083	0.0063	0.0024
18,000-20,000 lb.	0.1927	0.3081	0.0363	0.2605	0.0363	0.0148	0.0446	0.0076	0.0041	0.0130	0.0098	0.0037
20,000-22,000 lb.	0.2875	0.4598	0.0542	0.3888	0.0542	0.0221	0.0666	0.0113	0.0061	0.0194	0.0147	0.0055
22,000-24,000 lb.	0.4137	0.6616	0.0780	0.5595	0.0780	0.0318	0.0958	0.0162	0.0088	0.0279	0.0211	0.0080
24,000-26,000 lb.	0.5775	0.9236	0.1089	0.7810	0.1089	0.0443	0.1337	0.0227	0.0123	0.0389	0.0295	0.0111
26,000-28,000 lb.	0.7857	1.2565	0.1481	1.0625	0.1481	0.0603	0.1819	0.0308	0.0167	0.0529	0.0401	0.0151
28,000-30,000 lb.	1.0457	1.6723	0.1971	1.4141	0.1971	0.0803	0.2420	0.0411	0.0222	0.0704	0.0534	0.0201
30,000-32,000 lb.	1.3654	2.1835	0.2574	1.8464	0.2574	0.1048	0.3161	0.0536	0.0290	0.0919	0.0697	0.0263
32,000-36,000 lb.	1.9757	3.1596	0.3725	2.6717	0.3725	0.1517	0.4573	0.0776	0.0420	0.1330	0.1008	0.0380
36,000-40,000 lb.	3.0827	4.9300	0.5812	4.1688	0.5812	0.2366	0.7136	0.1210	0.0656	0.2075	0.1573	0.0593
40,000-45,000 lb.	4.8234	7.7138	0.9094	6.5227	0.9094	0.3703	1.1165	0.1894	0.1026	0.3247	0.2462	0.0928
45,000-50,000 lb.	7.5262	12.0361	1.4189	10.1777	1.4189	0.5777	1.7421	0.2955	0.1600	0.5067	0.3841	0.1447
50,000-55,000 lb.	11.2315	17.9618	2.1175	15.1884	2.1175	0.8622	2.5998	0.4410	0.2388	0.7561	0.5733	0.2160
55,000-60,000 lb.	16.1612	25.8454	3.0469	21.8547	3.0469	1.2406	3.7409	0.6345	0.3437	1.0880	0.8249	0.3108
60,000-65,000 lb.	22.5591	36.0771	4.2530	30.5066	4.2530	1.7317	5.2219	0.8857	0.4797	1.5187	1.1514	0.4339
65,000-70,000 lb.	30.6914	49.0825	5.7862	41.5039	5.7862	2.3560	7.1044	1.2050	0.6526	2.0662	1.5665	0.5903
70,000-75,000 lb.	40.8464	65.3226	7.7007	55.2365	7.7007	3.1355	9.4550	1.6037	0.8686	2.7498	2.0848	0.7856
75,000-80,000 lb.	120.4193	192.5778	22.7025	162.8427	22.7025	9.2437	27.8743	4.7279	2.5607	8.1067	6.1462	2.3159