VEHICLE COST RESPONSIBILITY STUDY (SJR 121)

PREPARED BY THE
VIRGINIA DEPARTMENT OF TRANSPORTATION

FOR THE
JOINT LEGISLATIVE AUDIT
AND REVIEW COMMISSION

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EXECUTIVE SUMMARY

INTRODUCTION

The General Assembly, through Senate Joint Resolution 121 (SJR 121) required the Virginia Department of Transportation (VDOT) to "... review the cost responsibility of vehicle classes using the highways, roads and streets of the Commonwealth and make recommendations to the 1991 General Assembly on the need for modifications to the current mix of revenues from the vehicle classes." In order to meet that requirement, the costs of highway construction and maintenance occasioned by various vehicles was determined and compared with the revenues generated by these same vehicles. This report presents a description of the issues, the methodology employed, and the analyses performed to determine whether vehicles are paying their fair share of the highway costs.

Overall study direction was provided by VDOT's Office of Policy Analysis, Evaluation and Intergovernmental Relations. Individuals from the Policy Office and the Transportation Research Council developed the methodological guidelines which were reviewed and approved by the Joint Legislative Audit and Review Commission (JLARC) staff. Technical assistance on costs to design, construct, and maintain the roads and structures in the Commonwealth was provided by a team of specialists in pavement and bridge design, maintenance, finance, and traffic engineering. Technical assistance was also provided by the Department of Motor Vehicles (DMV), the State Corporation Commission (SCC), and the Department of Taxation. These agencies were consulted to provide the best approach to estimating revenues and relating them to vehicles. Public meetings were held to obtain concerns and comments. Periodic meetings were also held with individuals representing the Automobile Association of America, Virginia Trucking Association, Council on the Environment, Virginia Road and Transportation Builders Association, Virginia Municipal League, Virginia Association of Counties, Virginia Railroads, and two-axle/three-axle truck groups.

HISTORY
(pp. 1-3)

In 1980, the General Assembly mandated a study by JLARC of whether there had been a "...fair apportionment and allocation of the cost of building and maintaining the roads and bridges of the Commonwealth between motor vehicles of various sizes and weights." The analysis indicated that basic equity was achieved except for medium-sized (two-axle six-tire) trucks, which significantly underpaid user fees relative to their responsibility. There was a slight tendency for cars and pickup trucks (two-axle four-tire trucks) to overpay and heavy vehicles (other trucks and buses) to underpay, although the imbalance was not significant.

Since 1981, changes have occurred in Virginia's transportation system and in the volume and mix of traffic using the roads. In addition, the composition of revenues and sources of funds has been altered through the enactment of landmark legislation in 1986. Recognizing the magnitude of changes in system usage and funding, the General Assembly mandated the updating of the study. The methodology outlined in the 1981 study, Vehicle Cost Responsibility in Virginia, served as the framework for this analysis, although several methodologies that were introduced in the Federal Cost Allocation Study and by other states were also employed.

PURPOSE AND SCOPE
(pp. 3-4)

Following the mandate set forth in SJR 121, the overall purpose of this study is to review the cost responsibility of vehicle classes and to make recommendations to the 1991 General Assembly regarding the need to modify the current revenue mix.

Two general principles guided the design of this vehicle cost responsibility study:

- the highway system should be basically user financed, and
- vehicles should be charged in relation to the costs they occasion.

Thus, the direct costs of the highway system are assigned to vehicle groupings in accordance with the costs occasioned by them. And, the user tax structure is evaluated to determine if the distribution of tax burden among classes of users matches the distribution of costs.

For the purposes of this study, the costs allocated are expenditures on the highway system. These include costs for administration, planning, safety programs, road construction, highway rehabilitation, road maintenance, and costs to construct, rehabilitate, and maintain bridges. Revenues attributed in this study include those user taxes and fees that support funds dedicated to highway maintenance and construction activities.

STUDY APPROACH
(pp. 5-10)

The cost responsibility study was conducted during the 1988-1990 biennium. Overall study direction was provided by VDOT's Office of Policy Analysis, Evaluation and Intergovernmental Relations. Individuals from the Policy Office and the

Transportation Research Council developed the methodological guidelines which were revised and approved by JLARC staff. Technical assistance on costs to design, construct, and maintain the roads and structures in the Commonwealth was provided by a team of specialists in pavement and bridge design, maintenance, finance, and traffic engineering.

Technical assistance was also provided by the Department of Motor Vehicles (DMV), the State Corporation Commission (SCC), and the Department of Taxation. These agencies were consulted to determine the best approach to estimating revenues and relating them to vehicles.

Vehicle Classes

Nine vehicle classes were identified based on differences in vehicle configuration and number of axles. Due to the lack of detailed revenue data, vehicles were combined into five classes to compare cost responsibility and revenue adequacy, as displayed in Table A.

TABLE A

Vehicle Classes And
Terminology Used for the Cost Responsibility Study

Passenger/Personal Use Vehicles
- Cars, Motorcycles
- 2-axle, 4-tire trucks

Buses
- Buses

Light Trucks
- 2-axle, 6-tire trucks

Single-Unit Trucks
- 3-axle, single-unit trucks
- Four or more axle single-unit trucks

Combination Vehicles
- Four or less axle combination trucks
- Five or more axle combination trucks
- Five or more axle multitrailer trucks

COST ALLOCATION
(pp. 10-40)

Overview

Allocable and Nonallocable Expenditures

Consistent with general practice, the costs allocated in this study are expenditures on the highway system. These include costs for administration, planning, safety, road and bridge construction, rehabilitation and maintenance. Excluded from allocation are monies in the Highway Maintenance and Operating Fund (HMOF) and the Transportation Trust Fund (TTF) that are not expended on roads or bridges and funds transferred to localities.

Expenditure data were collected for fiscal years 1987 through 1989, indexed to 1989 dollars, and averaged. The total amount to be allocated to vehicle classes was $1,458,807,490. Of this, $848 million was spent on construction, $210 million on resurfacing, and $401 million was expended for administration and general maintenance.

Cost Allocation Categories

The costs in this study were categorized by allocation method within major program expenditure areas. The program areas included road construction, bridge construction, and an administration and general maintenance category. Within these, costs were further subdivided into groups to which an allocation method could be assigned. This provided both a logical framework for discussing costs and the classification needed for their allocation.

Cost assignment followed a "cost-occasioning" approach in which costs attributed to vehicle types are those necessitated by some size or weight requirement of the vehicle. For example, a heavier vehicle requires greater pavement strength and a wider vehicle requires greater pavement width. The difference in vehicle weight or size thus necessitates or occasions specific costs. Costs not attributable to specific vehicle classes based on size or weight, are non-occasioned or common costs. These are allocated to all vehicle classes based on system use or travel characteristics. Examples of common costs include administration and general maintenance costs.

Road construction costs were subdivided into: preliminary and construction engineering, right-of-way acquisition, grading, drainage, shoulder construction, lane width beyond the minimum needed for the smallest vehicle class, and pavement construction.

Bridge construction costs included preliminary and construction engineering, shoulder and lane width requirements, as well as structural costs.

A variety of allocation methods were used for subprogram costs for bridge and road construction depending on whether the cost was occasioned or non-occasioned.

Ordinary maintenance, administration, and safety programs are costs that are common to all vehicle classes and are included as common costs. In addition, other costs that were shared equally by vehicles in some but not all classes, are called vehicle class shared costs. These refer to ferry administration that is allocable only to personal vehicles and weighing programs that affect trucks.

Travel and Weight Data

Measures of travel by vehicle class and operating weight are needed to calculate and allocate costs. In this study, vehicle miles traveled (VMT) from the Highway Performance Monitoring System (HPMS) provided travel data for the vehicle classes. The Truck Weight Study and a special study using weigh-in-motion equipment provided operating weight data by vehicle class.

Roadway Cost Allocation

The traditional way of allocating pavement construction costs is based on a design approach. The essential feature of this approach is that pavement costs are allocated to vehicles based on the thickness increment required to accommodate each vehicle type. Because pavement thickness is a function of the axle weight of the vehicle, heavier vehicles require thicker pavements and are, therefore, accorded more of the costs.

A revised version of this design method was employed to calculate the costs for each vehicle class. First the cost of the thinnest possible pavement able to carry the smallest vehicle was identified. This cost was allocated to all vehicles by their miles traveled. Then, the remaining costs were assigned to vehicles based on their axle weights and mileage. The costs associated with building wider lanes were charged to buses and trucks according to their travel. Roadway costs associated with right-of-way acquisition and preliminary and construction engineering were allocated to all vehicles. Grading costs, occasioned by the needs of the heavier vehicles, were assigned to three-axle and larger vehicles differentially, based on weight and class-related parameters. Costs associated with building drainage facilities to accommodate the two-axle, six-tire and larger vehicles were calculated and assigned to these vehicles.

Roadway construction costs were derived at the project level. All projects begun and completed since 1986 were identified, and a random sample for each administrative highway system was selected for analysis. The cost shares derived at the project level were then aggregated across all projects.

Summary of Roadway Costs

The results indicate that 65 percent of the roadway costs were allocable to personal use vehicles, two percent to buses, seven percent to two-axle six-tire trucks, three percent to single units, and 22 percent to combination vehicles. Within the five and more axle semitrailer class, 36 percent of the costs were attributed to vehicles operating over 70,000 pounds. A significant proportion of the costs for multitrailer trucks were also assessed for vehicles operating at that weight.

Bridge Cost Allocation

The cost responsibility of the vehicle classes for structures was also estimated using a design-based approach. Bridge design differs from pavement design, however, in that most of the costs are related to capacity (e.g., the number of lanes) and strength (e.g., the size of the supporting members). The strength is required to support the weight of the bridge itself, commonly called the dead load, and the weight of vehicles crossing the bridge, the live load. In this study, costs were attributed to the various classes and weights of vehicles on the basis of the design strength required to accommodate their portion of both dead and live load. The costs associated with lane width requirements beyond that needed for smallest vehicles were attributed to larger vehicles. Costs for both new and replacement structures were allocated in the same manner.

Bridge costs vary by type of material and by span length. The most common bridge types were identified and the expenditures for each separately determined. Twelve bridge types accounted for 88 percent of the bridges built over the last ten years in the Commonwealth. For each bridge type, the cost associated with the design increment needed for various vehicle classes and weights was calculated. These costs were then allocated to the vehicle class or classes that necessitated the increase. All vehicles shared the minimum structure cost on the basis of VMT. Costs beyond the minimum were distributed on the basis of VMT and incremental cost occasioned by the particular vehicle class/weight group combination. The total of the minimum and incremental cost for each vehicle class/weight group combination determined its cost share factor. The cost shares were used to apportion the expenditures for each bridge type to each vehicle at each weight group.

The required width of an individual traffic lane is a function of the type of traffic expected on the bridge. It is logical that a structure designed to carry only cars and light trucks could be narrower than those designed to common standards. To allocate the costs of the additional width, each of the prototype bridges was designed for narrow lanes using the light loading. The cost of the wider deck width was assigned to buses and three-axle or larger trucks.

Engineering costs were allocated to vehicles in the same manner as they were for pavements.

The results indicate personal use vehicles (passenger cars, cycles, vans, pick-ups) were responsible for 60.0 percent of the costs, single unit trucks for 10.9 percent, and trucks with five or more axles for 23.6 percent of the costs associated with bridge construction. The costs for the nine vehicle classes, for each of the weight groups, provide an indication of the greater responsibility associated with heavy, short-wheelbase vehicles. A disproportionate amount of stress is produced on bridges by single units operating over 70,000 pounds and this is reflected in their cost responsibility.

Common Cost Allocation

Common costs are not caused by particular vehicle attributes and were, therefore, allocated differently than construction costs. It was assumed that facilities and services are made necessary by the need for travel and are consumed regardless of the type of vehicle operating on the roadway. The quantity of such services is assumed to vary based on the amount of travel; accordingly, VMT was used to allocate common costs.

Common costs and vehicle class shared costs accounted for 27.4 percent of the total costs to be allocated, 90.0 percent of which were occasioned by personal use vehicles. Because the allocator was VMT, cars and two-axle, four-tire trucks were responsible for the largest portion of safety, administration, planning, research, and common maintenance costs.

Total Costs

Personal use vehicles account for 71.1 percent of the total cost responsibility. Buses are assessed 2.0 percent of the cost responsibility; light trucks, 5.3 percent; single units 4.0 percent; and, combination trucks, 17.7 percent.

REVENUE ATTRIBUTION
(pp. 41-58)

For the purposes of this study, revenues to be attributed to the vehicle classes are limited to those highway user taxes and fees that support the Highway Maintenance and Operating Fund and the portion of the Transportation Trust Fund dedicated to highway construction. Toll facility revenues were excluded, as were federal funds for non-highway purposes, local government contributions, the aviation fuel tax portion of special fuels, the portion of rental tax that reverts to localities, administrative expenses earmarked for the Department of Motor Vehicles, and liquidated damages for overweight trucks. The general sales tax is not considered a user fee because it is not paid exclusively by highway travelers and is therefore not attributed. The tax is used to offset the user fee monies provided to other agencies and thus not available for use on highways. Any remaining amount of the sales tax revenue might be considered a benefit to all vehicle classes.

Fuel Tax and Road Use Taxes

The Commonwealth levies a fixed cents-per-gallon tax on fuel purchased within the State. Currently, the motor fuel tax equals 17.7 cents per gallon and the diesel fuel tax equals 16.2 cents per gallon. Private and for-hire motor carrier owners and operators pay a road use tax of 19.5 cents per gallon for vehicles with more than two axles. The State Corporation Commission credits those motor carriers paying road use taxes 16.0 cents per gallon for fuel purchased within the Commonwealth. Motor fuels, special fuels, and road use taxes contributed 45 percent of the total state revenues for highways in fiscal years 1988 and 1989. Taxable gallons of fuel, and therefore fuel and road use taxes, are functions of vehicle miles traveled and fleet fuel efficiency. For this study, fleet fuel efficiency estimates are based on data taken from the Motor Vehicle Manufacturers Association annual reports for 1989 and 1990.

Estimating the taxable fuel base requires dividing VMT by estimated fuel efficiency for each class to derive an estimate of gross gallons consumed. Several adjustments were necessary, however. First, gross taxable gallons were reduced by the amount of fuel used by public agencies. A second adjustment involved using the SCC fuel usage records as a check on taxable gallons attributed to vehicles subject to the road use tax. A third adjustment involved using DMV data to account for fuel tax refunds.

Motor Vehicle Sales and Use Tax

Approximately 20 percent of the total state revenue collections come from the three percent tax imposed on the sale and rental price of motor vehicles. The attribution of these revenues is based on the results of a special study conducted by DMV of actual payments by vehicle class for the study period.

Motor Vehicle License and Registration Fees

All vehicles registered in Virginia are required to pay vehicle registration fees. Personal use vehicle fees are relatively flat in relation to weight whereas truck fees are graduated on gross weight. Vehicles that operate in interstate commerce are registered under the Interstate Registration Plan and pay fees based on their proportion of travel in Virginia.

Data maintained by DMV on actual fees collected were used to attribute revenue to the vehicle classes.

Federal Revenue Attribution

At the time of the study, the federal government levied a 9.1 cents-per-gallon tax on gasoline and a 15.1 cents-per-gallon tax on diesel fuel. One-tenth of one cent per gallon supported the Federal Leaking Underground Petroleum Storage Tank Trust Fund and was excluded from attribution. Also excluded was the one cent per gallon dedicated to the Federal Transit Fund. Calculation of federal fuels tax payments was relatively straightforward and followed the method described above for the attribution of state fuel taxes.

In addition to federal taxes on fuel, three federal excise taxes provide revenue for the federal-aid program:

- a graduated truck tire tax,
- a 12 percent sales tax on the retail price of tractors, trucks greater than 33,000 pounds GVW, and trailers greater than 26,000 pounds GVW, and
- a tax on vehicles registered at gross weights above 55,000 pounds.

The tire excise tax was attributed on the basis of the vehicle miles traveled by each truck class weighted by the number of tires used by each typical truck in the class. A special analysis of actual sales tax collections conducted by DMV provided the information for attribution of the federal tax. The Federal Highway Administration reports the amount of the heavy vehicle use tax attributed to vehicles in Virginia.

Total Revenues

The state and federal revenue attribution by class for the two year average is as follows: 75.5 percent of the revenues are attributed to passenger vehicles, .6 percent to buses, 4.1 percent to light trucks, 3.3 percent to single units and 16.5 percent to combinations.

CONCLUSIONS
(pp. 58-65)

Costs Versus Revenues

To determine whether vehicle classes met their cost responsibility, it was necessary to compare the proportion of costs attributable to the vehicle classes with the proportion of revenues paid. Because revenues could only be estimated for five vehicle classes, costs were aggregated to the same classes for comparison purposes.

The revenue-to-cost ratios based on these proportions are as follows:

Revenue-to-Cost Ratios
(revenue share/cost share)

Passenger Vehicles	1.06
Buses	.30
Light Trucks	.77
Single Units	.85
Combinations	.93

The revenue-to-cost ratio represents the proportionate share of revenues received for each percent of cost. A ratio of 1.00 means revenues exactly balance costs. Ratios less than one represent an underpayment of that vehicle class, and ratios greater than one indicate an overpayment.

Comparison of the costs with revenues indicate that only cars and personal use trucks are paying taxes and fees proportionate to their cost responsibility. All other classes are underpaying, although to varying degrees. The revenue-to-cost ratio for personal use vehicles was 1.06. In a $1.5 billion program level, automobile owners would pay $66 million more than they occasion and approximately that same amount would not be collected from the vehicle classes that generate the cost. This example assumes that all revenues and costs are user-based and general sales tax revenues are not included.

Buses pay less than one third of their cost responsibility. While as a class they do not produce large costs, they are exempt from most user fees at both the federal and state level. Therefore, for the same program level example, buses would be underpaying by approximately $21 million.

The revenue-to-cost ratio of two-axle, six-tire vehicles was .77, indicating 23 percent of the share of costs attributable to light trucks is not collected from them. This translates into $18 million in the program example. Single unit trucks having three or more axles underpay approximately 15 percent of their cost responsibility, or $10 million given the example, while combination vehicles underpay by seven percent, or $17.5 million.

These results parallel those reported in the 1981 Virginia cost responsibility study. Table B presents the revenue-to-cost differences from both studies. It can be observed that the degree of overpayment by personal use vehicles and the degree of underpayment by combination vehicles have increased in magnitude over time.

TABLE B

Revenue to Cost Differences by Vehicle Class

	Percent	
	1981	1990
Passenger	+ 4.2	+ 6.2
Light Trucks & Buses	-38.0	-35.6
Single Units	-16.9	-15.0
Combinations	- .8	- 6.8

The differences in revenue and cost responsibility proportions are exacerbated at higher weights because responsibility increases geometrically with weight. Therefore, vehicles operating at the extreme ends of the weight spectrum produce considerably greater costs. Almost 82 percent of the four-axle, single units' cost responsibility was attributed to those vehicles operating over 70,000 pounds, for example.

As a way of estimating responsibilities of trucks operating overweight, a special study was performed. For single-unit trucks and tractor trailers operating over 80,000 pounds, the cost per mile exceeds the revenue collected. In particular, the fees obtained from overweight vehicles fails to compensate for the costs occasioned. The disparity between costs and revenues is greatest in the highest weight categories because of the fee schedule and the large number of vehicles that are permitted to operate free of charge. Costs escalate well beyond the ten cents a mile fee charged for overweight operations.

While bus and truck classes pay less than the costs they occasion, decisions regarding the appropriateness of the revenue mix need to be considered in light of the contribution of the general sales tax to transportation financing. The Commission on Transportation in the Twenty-First Century determined user fees alone were not enough to fund critical transportation needs and recommended the sales tax as an appropriate funding mechanism because of the essential role of transportation in the economic development of the Commonwealth. Thus, conclusions on the need to modify the tax structure will depend on the extent to which the General Assembly views the sales tax as a mechanism to offset shortages in user fee receipts for particular vehicle classes.

RECOMMENDED STUDIES

Cost responsibility studies focus on the relative vehicle revenue-to-cost shares. They also address a specific funding level and program emphasis which will change over time. It is, therefore, recommended that a cost responsibility study be undertaken on a periodic basis, at least every decade, and that supplemental studies be performed to ensure state-of-the-art developments in pavement and bridge theory can be incorporated in the study design.

If it is the desire of the General Assembly that VDOT undertake periodic cost responsibility studies, it is recommended that the Department conduct research on the relationship among traffic levels, vehicle weights, and pavement performance, and evaluate the potential use of deterioration models as a method to improve cost estimation.

If charged with another study, it would also be necessary for the Department to review its electronic data bases to ensure accessibility of information for that specific purpose.

Furthermore, if there is interest in determining user fee equity for a larger number of vehicle types or within classes, the revenue data must be more universally available by vehicle type and weight. Enhancements are needed in the collection, format, and retrieval capabilities of revenue data. A mandate by the General Assembly would ensure that the revenue agencies collect the information at the appropriate level of detail, but it should be recognized that additional costs would be incurred.

SENATE JOINT RESOLUTION 121
VEHICLE COST RESPONSIBILITY STUDY

INTRODUCTION

The General Assembly, through Senate Joint Resolution 121 (SJR 121), required the Virginia Department of Transportation (VDOT) to "... review the cost responsibility of vehicle classes using the highways, roads and streets of the Commonwealth and make recommendations to the 1991 General Assembly on the need for modifications to the current mix of revenues from the vehicle classes." In order to meet that requirement, the relationship between the costs of highway construction and maintenance occasioned by various vehicles and the revenues generated by these vehicles was examined. The purpose of the study was to determine whether the shares of taxes and fees paid on behalf of the various vehicle classes approximate the shares of costs attributable to those classes.

HISTORICAL BACKGROUND

1981 Virginia Cost Responsibility Study

In 1980, the General Assembly mandated a study by JLARC of whether there had been a "...fair apportionment and allocation of the cost of building and maintaining the roads and bridges of the Commonwealth between motor vehicles of various sizes and weights."[1] The analysis indicated that basic equity was achieved except for medium-sized trucks (two-axle, six-tire and single-unit trucks), which significantly underpaid user fees relative to their responsibility.[2] There was a slight tendency for cars and pickup trucks (personal use two-axle four-tire trucks) to overpay and heavy vehicles (other trucks and buses) to underpay, although the imbalance was not significant.

Since 1981, changes occurred in Virginia's transportation system and the volume and mix of traffic using the roads. Annual vehicle miles traveled (VMT) increased approximately 50 percent; 2,200 miles of road were added to the system; and, 743 new bridges were constructed in the Commonwealth.

The composition of revenues and sources of funds also changed through the enactment of landmark legislation in 1986 to generate

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1 Senate Joint Resolution 50 of the 1980 General Assembly.

2 Vehicle Cost Responsibility in Virginia., Virginia: Joint Legislative Audit and Review Commission, November 1981.

funds for the transportation needs of the Commonwealth. Among the revenue changes since 1981 were the following:

- o the gasoline tax increased several times from the 1981 rate of 9 cents per gallon to 17.7 cents per gallon,
- o the special fuels tax increased from 9 to 16.2 cents per gallon,
- o the road use fee increased from 11 to 19.5 cents,
- o the vehicle sales and use tax increased from 2 to 3 percent, and
- o the general sales tax increased from 3 to 3.5 percent, with the additional amount dedicated to the Transportation Trust Fund.

Recognizing the magnitude of the changes in system usage and funding, the General Assembly mandated the updating of the 1981 JLARC study. The methodology[3] outlined in the JLARC study served as the framework for this analysis, although several methodologies that were introduced in the Federal Cost Allocation Study[4] and by other states were also employed.

Federal Cost Allocation Study

Prior to the Federal Cost Allocation Study performed in 1982, all pavement costs were assigned using an incremental cost assignment approach. In the federal study, a distinction was made between the costs associated with new and rehabilitated pavements. New pavement costs were assigned based on current design practice, while rehabilitated pavement costs were assigned using a consumption-based approach. For the consumption-based approach, pavement distress models were developed to account for the factors directly related to traffic that caused pavement damage. In addition, inequalities of the incremental approach were eliminated with the application of a uniform assignment of pavement costs and a more in-depth approach was developed for bridge cost allocation.

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[3] Methodologies For a Vehicle Cost Responsibility Study., Virginia: Joint Legislative Audit and Review Commission, January 1981.

[4] Final Report on the Federal Highway Cost Allocation Study., Washington, D.C.: U.S. Department of Transportation, May 1982.

The Federal Highway Administration (FHWA) updated their cost responsibility study[5] in 1988 and specifically addressed heavy vehicle costs. This study confirmed the findings of the earlier federal study and state studies with regard to the relationship between pavement damage and axle load. The Heavy Vehicle Cost Responsibility Study concluded that for any vehicle configuration, heavier vehicles are less likely to pay their share of highway costs than lighter vehicles. The study also found that in any weight category, the greater the number of axles, the higher the ratio of revenues to costs.

Cost Allocation Studies Conducted by Other States

Since 1976, 24 states have conducted or initiated highway cost allocation studies, 17 of which were completed after 1982. There were some differences in how the revenues and expenditures were included and which items were treated as common costs. Revenue attribution was similar from study to study with differences accounted for by the revenue structure of the state. In general, the uniform method, recommended in the federal study, has been adopted by the states for allocating new highway construction expenditures. The assignment of cost responsibility to the vehicle classes was generally accomplished using VMT for common costs, equivalent single axle loads (ESALs) for pavement costs, and design live loading for bridges based on the federal method. The conclusions of the state studies varied depending on the extent of the system mileage as well as traffic patterns, pavement design, and management decisions unique to each state.

PURPOSE AND SCOPE

Guiding Principles

Following the language set forth in SJR 121, the overall purpose of this study is to review the cost responsibility of vehicle classes using methods approved by the Joint Legislative Audit and Review Commission (JLARC), and to make recommendations to the 1991 General Assembly regarding the need to modify the current revenue mix.

Two general principles guided the design of this vehicle cost responsibility study:

- o the highway system should be basically user financed, and

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[5] Heavy Vehicle Cost Responsibility Study., Washington, D.C.: U.S. Department of Transportation, November 1988.

- vehicles should be charged in relation to the costs they occasion.

Thus, the direct costs of the highway system must be assigned to vehicle groupings in accordance with the share of costs found to be occasioned by them. And, the user tax structure must be evaluated to determine if the distribution of tax burden among classes of users matches the distribution of costs.

For the purposes of this study, the costs allocated are expenditures on the highway system. These include costs for administration, planning, safety programs, road construction, highway rehabilitation, road maintenance, and costs to construct, rehabilitate, and maintain bridges and tunnels. Revenues attributed in this study include those user taxes and fees that support funds dedicated to roadway maintenance and construction activities.

Study Objectives

The major objectives of the study are as follows:

- identify major sources and mixes of revenue supporting the construction and maintenance of Virginia highways, roads, and streets,
- estimate the user revenues generated by the various vehicle classes,
- identify the construction and maintenance costs of the current program,
- develop and apply the latest scientific methods to estimate the portion of construction and maintenance costs occasioned by the various vehicle classes,
- compare occasioned costs with the user fees generated by the various vehicle classes,
- develop conclusions about the extent to which the costs are borne by the vehicle classes that occasion them and,
- develop recommendations for reviewing the assumptions and projections of the cost responsibility study on a periodic basis.

STUDY APPROACH

Overview

The cost responsibility study was conducted during the 1988-1990 biennium. Overall study direction was provided by VDOT's Office of Policy Analysis, Evaluation and Intergovernmental Relations. Individuals from the Policy Office and the Transportation Research Council developed the methodological guidelines which were revised and approved by JLARC staff. Technical assistance on costs to design, construct, and maintain the roads and structures in the Commonwealth was provided by a team of specialists in pavement and bridge design, maintenance, finance, and traffic engineering.

Technical assistance was also provided by the Department of Motor Vehicles (DMV), the State Corporation Commission (SCC), and the Department of Taxation. These agencies were consulted to determine the best approach to estimating revenues and relating them to vehicles.

To obtain input from the public, the study was announced in several newspapers in the Commonwealth, and public meetings were held to determine general concerns. Meetings with individuals representing the Automobile Association of America, Virginia Trucking Association, Council on the Environment, Virginia Road and Transportation Builders Association, Virginia Municipal League, Virginia Association of Counties, Virginia Railroads, and two-axle/three-axle truck groups were held at various junctures during the study.

Vehicle Descriptors and Data Bases Used

Vehicle Classes

Highway costs are a function of vehicle travel, with pavement costs a direct result of axle-weight miles. To allocate highway costs and related revenues to vehicles, a set of vehicle classes was, therefore, defined. Vehicles were grouped into nine classes based on vehicle configuration and number of axles. Due to the lack of detailed revenue data, vehicles were then combined into five classes for the comparison of revenues and costs. The nine classes displayed in Table 1 include all configurations of highway vehicles. Also indicated are the five major vehicle classes used in the analysis of revenues, and thus, for cost responsibility assessments. The abbreviations listed were used primarily in table presentations due to space limitations.

TABLE 1

Vehicle Classes:
Terminology and Abbreviations Used
for the Cost Responsibility Study

Terminology Used	Abbreviations Used
Passenger/Personal Use Vehicles	
Cars, motorcycles	Car/cycle
2-axle, 4-tire trucks	2A4T
Buses	
Buses	Bus
Light Trucks	
2-axle, 6-tire trucks	2A6T
Single-Unit Trucks	
3-axle, single-unit trucks	3ASU
Four or more axle single-unit trucks	4+ASU
Combination Vehicles	
Four or less axle combination trucks	4-AST
Five or more axle combination trucks	5+AST
Five or more axle multitrailer trucks	5+AMT

Vehicle Miles Traveled

Since the last Virginia cost responsibility study, travel increased approximately 50 percent. Heavy truck travel increased at an even greater rate. Figure 1 presents the amount of truck VMT on the interstate, primary, and arterial roads over time. Traffic continues to grow, but the rate of increase is slowing. From 1985 to 1986, VMT increased 7.92 percent; from 1986 to 1987 it increased by 6.01 percent; and, from 1987 to 1988, the increase was 4.49 percent.

The VMT data from the Highway Performance Monitoring System (HPMS) was employed in this study. These data come from 2,600 sample sites around the Commonwealth which were selected to be representative of statewide VMT. Table 2 presents the statewide VMT for fiscal year 1989 for each of nine vehicle classes used in the study. Vehicle travel at the project level was also employed

FIGURE 1

ANNUAL VMT FOR HEAVY TRUCKS
INTERSTATE, ARTERIAL, AND PRIMARY ROADS

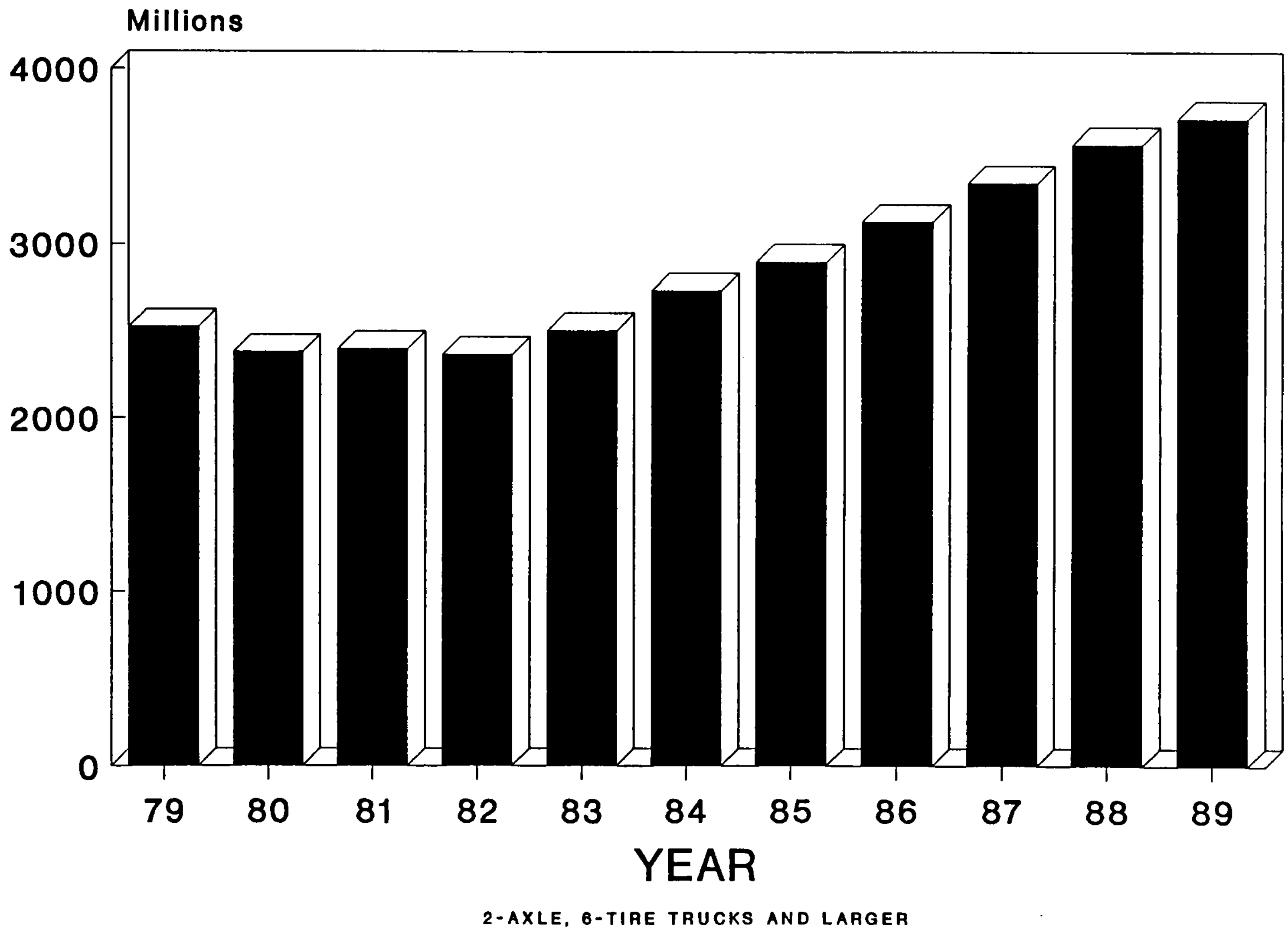


TABLE 2

Fiscal Year 1989 Travel by Vehicle Class

Vehicle Class	HPMS VMT (in millions)	Percentage of Travel
Cars/motorcycles	40,715	70.87
2-axle, 4-tire, trucks (light trucks)	11,724	20.41
Buses	488	0.85
2-axle, 6-tire trucks	1,552	2.70
3-axle, single-unit trucks	493	0.86
4 or more axle single-unit trucks	42	0.07
4 or less axle combination trucks	185	0.32
5 or more axle combination trucks	2,203	3.83
5 or more axle multitrailer trucks	51	0.09
Total	57,453	100.00

Note: VMT does not add to total due to rounding in the calculation of costs. The average daily traffic (ADT) obtained from counts at specific sites were used in pavement costing.

Vehicle Weights

Data on truck weights were obtained from the 1989 Truck Weight Study (Summer Survey), and were adjusted with data from special studies. A distribution of operating weights for each of the nine vehicle classes described earlier was estimated and then combined with statewide travel data to obtain VMT by weight for the nine classes.

The Summer Survey is a biennial study conducted at 19 selected sites throughout the Commonwealth. Vehicle counts, weights, axle weights, and axle spacings are collected during this survey. Since truck weight data are gathered with law enforcement present, scale avoidance was considered likely. A study conducted in 1987 found that 23 percent of the trucks using a scale bypass route were attempting to avoid the scales, and that 22 percent of the trucks were, in fact, overweight. A special study, using weigh-in-motion (WIM) equipment, was, therefore, conducted to address the problem of scale avoidance. The WIM study was designed to identify those vehicles that operate overweight and is believed to be representative of the true proportion of overweight vehicles. Information from this study was used to adjust the Summer Survey data. The procedure for adjusting the Summer Survey involved weighting the Summer Survey vehicle count by the HPMS proportions. The resulting VMT shares by class and weight were then applied to total statewide VMT from HPMS. The travel for federally owned roads and toll facilities was removed from HPMS data prior to its distribution by class and weight.

Hauling Permits

The truck weighing program was instituted to enforce the federal and state weight laws. Requirements presently restrict vehicles to 20,000 pounds for single axles, 34,000 pounds for a tandem axle, and 80,000 pounds overall gross vehicle weight. There are, however, trucks legally running over the 80,000 pound limit. The Department issues overweight and oversize permits for indivisible loads and for special commodity carriers. Upon request, a single trip permit or blanket permit may be obtained. The trip permit costs $10.00 and is valid for the duration of one specified haul; the blanket permit costs $60.00 and is valid for two years. In addition, a mileage fee may be charged.

In fiscal year 1989, 66,435 permits were issued, of which 9,883 were blanket permits covering more than one trip. Permits were issued to carry manufactured housing, boats, concrete mixed in transit, specialized equipment, containerized cargo, farm produce, coal and solid waste. Haulers of these commodities, except for boats and manufactured housing, are exempt from paying for the permits. In addition, permits were provided to federal, state, and local governments. In fiscal year 1989, 7,310 free permits were issued.

Public Vehicles

In 1989, 4,803,557 vehicles were registered in Virginia, of which 4,511,165 were passenger vehicles. As of July, 1989 there were 69,975 vehicles with municipal or state license plates operating in the Commonwealth. None of the public vehicles pay use fees, although their mileage was included in the statewide VMT. The public vehicle fleet represented approximately 1.5 percent of all vehicles and the publicly owned trucks represented 2.8 percent of the truck fleet. In order to provide an indication of the size of this subsidy, mileage and weight information were collected from a survey of municipal governments. Information was obtained for state vehicles through the Central Garage.

ORGANIZATION OF REPORT

The following sections of this report provide the methodological basis and results of the Vehicle Cost Responsibility Study. It is organized into three sections: Cost Allocation, Revenue Attribution, and Conclusions.

COST ALLOCATION

OVERVIEW

Expenditures as the Basis for Cost Allocation

Consistent with general practice, costs to be allocated are defined as highway maintenance and construction expenditures. This assumes that adequate funds are spent on the highway system. Where expenditures are not enough to cover the actual damage that is being done to the roads or bridges, it could be argued that disinvestment in the highway infrastructure is occurring. Expenditures were used because there is no expectation of a future change in the program funding and because the present program level represents that amount the public, through the General Assembly, is willing to spend on roadways in the Commonwealth. In addition, the objectives of cost allocation studies are to evaluate user fee structures and to determine if the fees paid by vehicle classes are proportional to the relative share of the program costs. Questions of disinvestment are thus ignored in this analysis and are considered more appropriate for another study.

Expenditure Trends

Figure 2 represents VDOT program expenditures for fiscal years 1980 through 1989 and the Department's forecast of expenditures for fiscal years 1990 through 1995. The construction program has been increasing since 1982, peaked in 1989, and will begin to level off in 1991. From 1991 to 1995, the Department's program is expected to be relatively stable with the only significant change being a reduced level of activity on the interstate system because of the anticipated decrease in federal funding. For that reason, an average of several years was considered to better reflect expenditures levels than the use of fiscal year 1989. In Figure 2, expenditures are presented for four program areas: construction, ordinary maintenance, maintenance replacement, and other. This last group of expenditures includes administration, research, safety, planning, and truck weighing programs. As shown in Figure 3, except for the interstate program, the relative level of construction expenditures across administrative systems was projected to remain relatively stable through fiscal year 1995. The winding down of the federal interstate construction program through 1992 is shown in this figure, which also explains the falling construction dollars in Figure 2.

Figure 4 presents the overall stability of the maintenance program on the interstate, primary, and secondary highway systems. In this figure, a short-lived increase in interstate maintenance in fiscal year 1990 and a decrease in maintenance on the secondary system in fiscal year 1989 can be observed. Fluctuations such as these can be caused by unusual weather conditions or other unanticipated events.

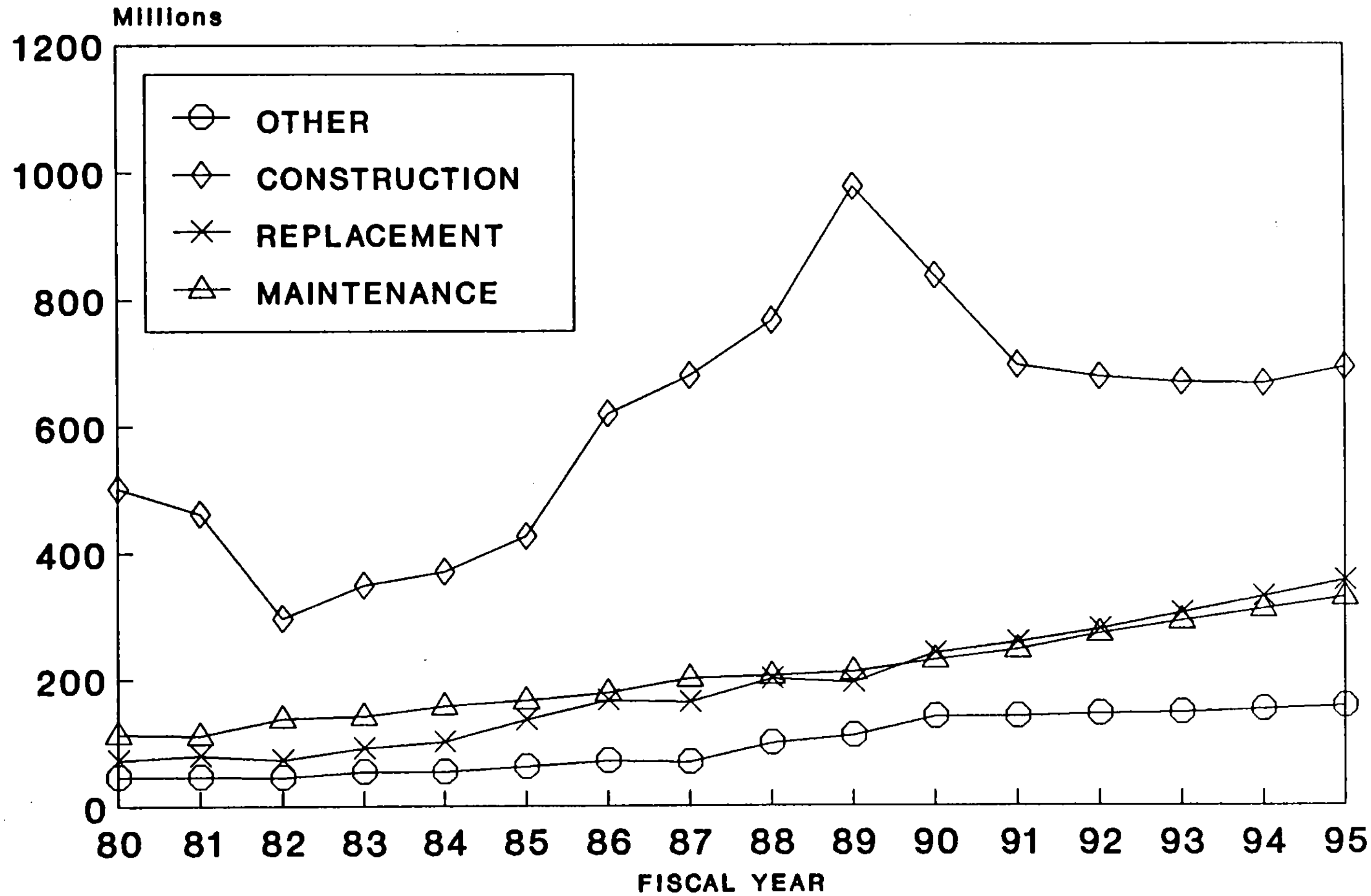
Allocable and Nonallocable Expenditures

Monies that were not expended on roadways and bridges and monies that were earmarked for particular projects but not generated by user fees were excluded from analysis. Also, certain funds were not allocable because they were forwarded to another unit of government. VDOT expenditures for mass transit assistance, for ports and airports, and for support to other state agencies were thus excluded from allocation. Monies such as local government expenditures under revenue sharing projects, and money spent on coal severance tax roads were not obtained through highway user fees and thus were not considered allocable expenses. Because toll roads are in general self-supporting, toll expenditures were

FIGURE 2

PROGRAM EXPENDITURES*

FISCAL YEARS 1980 - 1995

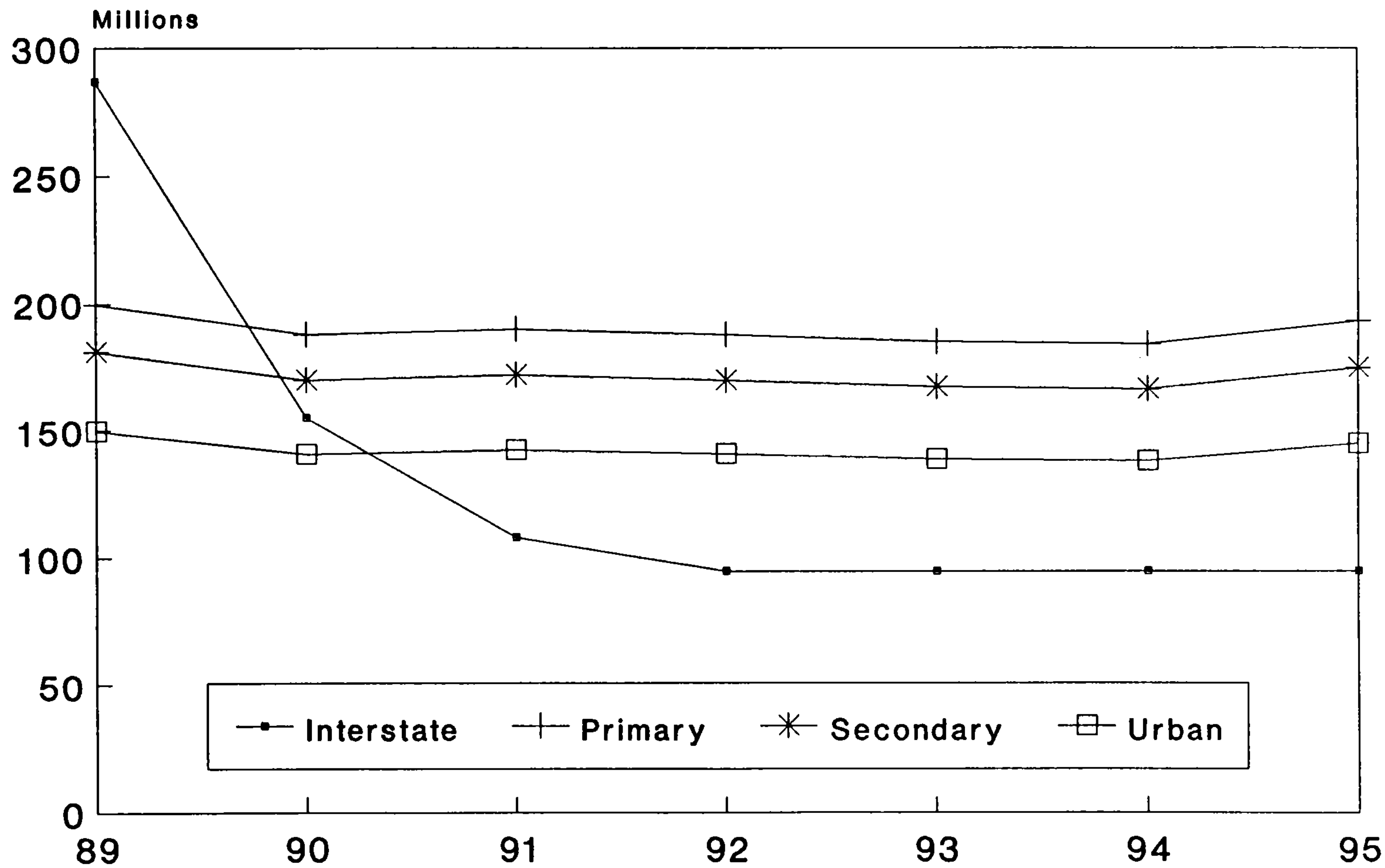


*FY90-95 ARE FORECASTED EXPENDITURES

FIGURE 3

CONSTRUCTION BY SYSTEM

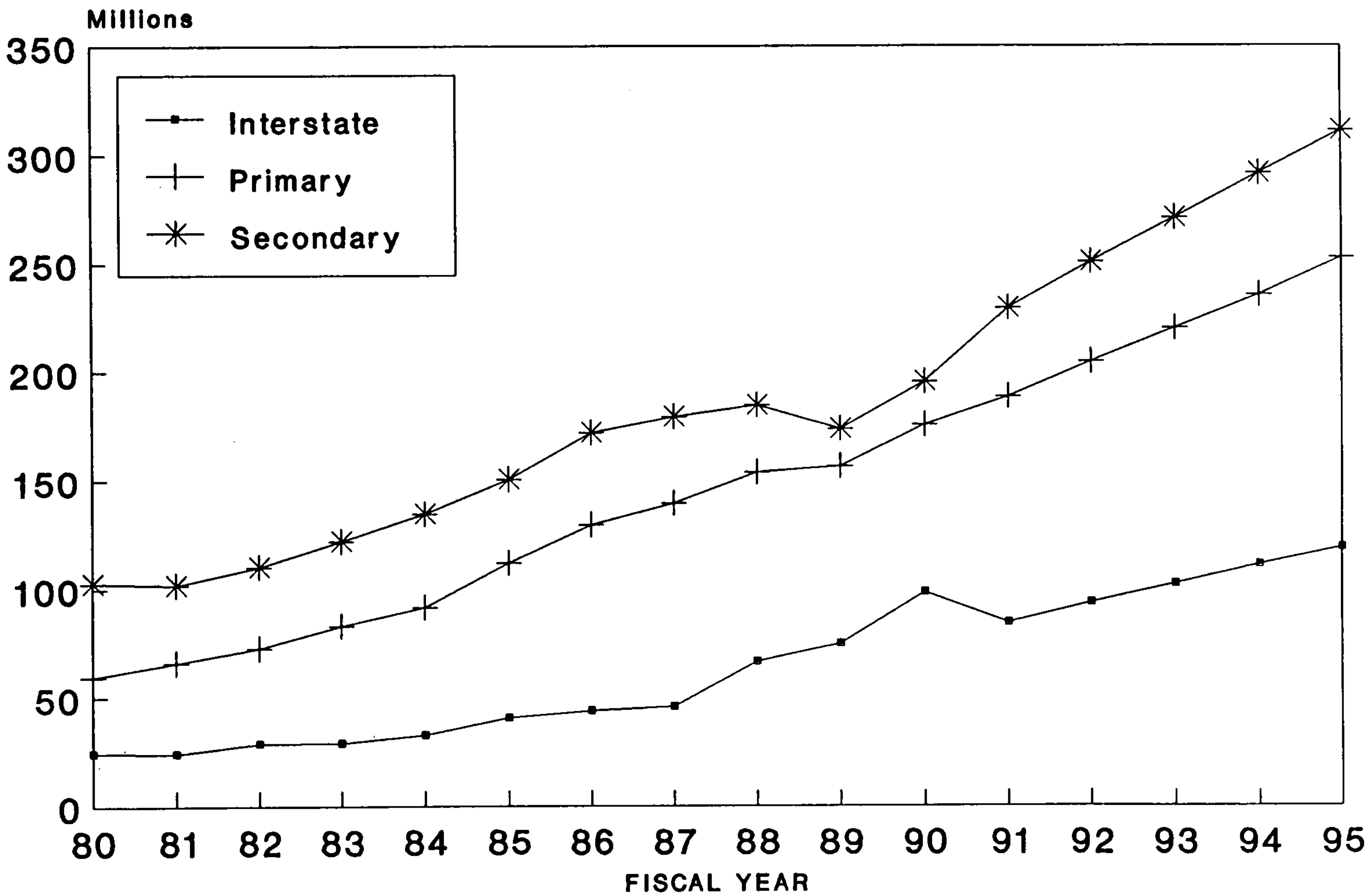
FISCAL YEARS 1989 - 1995



FY90-95 ARE FORECASTED EXPENDITURES

FIGURE 4

MAINTENANCE PROGRAM
BY ADMINISTRATIVE SYSTEMS



FY90-95 ARE FORECASTED EXPENDITURES

also eliminated. The remaining expenditures for roadway and bridge construction, maintenance, and administration were allocable. Also allocable were expenditures on ferries, truck weighing programs, safety programs, and roadside improvement.

Estimation of Allocable Expenditures

In this study, expenditures for fiscal years 1987 through 1989 were indexed to 1989 dollars, using the VDOT construction index (fiscal year 1987 = 1.141, fiscal year 1988 = 1.061, fiscal year 1989 = 1.0), and averaged to better represent Department expenditures. VDOT's fiscal records were employed for the expenditure data, but when breakdowns needed for allocation were not available from fiscal records, maintenance and construction expenditure reports were employed in the development of estimates.

The total allocable expenditures in 1989 dollars used in this study was $1,458,807,489. Table 3 presents a breakdown of these expenditures into construction and resurfacing expenditures for roadways and bridges, and other expenditures (e.g., administration costs). The types of construction funds are presented in Table 4. It is important to note that these categories are not comparable to VDOT program categories but are instead allocation classifications. These expenditures are presented to indicate the amount of costs that were allocated.

TABLE 3

VDOT Expenditures
Allocated by the Cost Responsibility Study

Three Year Average (Fiscal Years 1987-1989)
In 1989 Dollars

Construction	$ 848,319,648
Resurfacing	209,848,738
Other	400,639,103
Total	$1,458,807,489

TABLE 4

VDOT Construction Expenditures

Three Year Average (Fiscal Years 1987-1989)
In 1989 Dollars

Preliminary Engineering	$ 71,688,175
Right-of-Way	110,040,998
Construction	619,152,711
Construction Engineering	47,437,764
Total	$848,319,648

Cost Allocation Categories

The costs in this study were categorized by allocation method within major program expenditure areas. The program categories and allocation methods are displayed in Table 5.

The major program expenditures included road construction, bridge construction, and other costs. Within these, costs were further divided into subprogram categories based on allocation method. Thus, the program dimensions listed in Table 5 provide both a logical framework for discussing costs and the classification needed for allocation.

Cost assignment followed a "cost-occasioning" approach in which costs attributed to vehicle types are those necessitated by some size or weight requirement of the vehicle. For example, a heavier vehicle requires greater pavement strength and a wider vehicle requires greater pavement width. The difference in vehicle weight or size thus necessitates or occasions specific costs. Costs not attributable to specific vehicle classes based on size or weight, are non-occasioned or common costs. These are allocated to all vehicle classes based on system use or travel characteristics. Examples of common costs include administration and general maintenance costs.

A subset of costs included with the common costs are those attributable to particular vehicle classes but not based on the vehicle size or weight. Vehicle class shared costs are joint costs for specific vehicle classes, such as the costs associated with the truck weighing program that is attributable to all trucks, but not cars or buses. Because the costs are unrelated to vehicle dimensions they are allocated to the appropriate class by their amount of travel.

Occasioned costs are allocated to classes through use of scientifically established methods that relate design requirements to vehicles. The applicable design-based allocators are ESALs for pavements and live-load moments for bridges. The methods will be described in later sections of this report.

As can be seen in Table 5, construction expenditures were divided into those for roads and those for bridges. Roadway expenditures for new and rehabilitated pavements were allocated by project level traffic and ESALs. Other roadway construction expenditures such as those for preliminary engineering, right-of-way acquisition, and construction engineering were also allocated by project traffic. Grading was allocated incrementally using vehicle size and weight information.

Expenditures for bridge and drainage construction were allocated incrementally using axle weight and spacing information. The preliminary engineering and construction engineering costs for structures were allocated by vehicle miles traveled.

Common costs included expenditures for administration, planning, research, and general maintenance. These were allocated by VMT.

The vehicle class shared costs were allocated by the VMT of the appropriate class.

ROADWAY COST ALLOCATION

Theoretical Basis of Pavement Cost Allocation

Thickness Costs

The traditional way of allocating pavement thickness costs occasioned by vehicles is based on a design approach. The costs of the total pavement are separated into components based on the thickness-to-weight relationship inherent in the design standards. The basic feature of this method is that pavement costs are allocated to vehicles based on the different thickness increment required to accommodate each vehicle type. Because pavement thickness is a function of the axle weight of the vehicle, heavier vehicles require thicker pavements and are, therefore, accorded more of the costs.

TABLE 5

Cost Categories and Allocation Method

Category	Allocation Method
I. Road Construction	
Preliminary & Construction Engineering	Project VMT (ADT)
Right-of-Way	Project VMT (ADT)
Grading	Incremental
Drainage	< 10 feet Incremental > 10 feet by VMT
Shoulder Construction	2 Increments
Lane Width	2 Increments
New & Reconstructed Pavement	Minimum Pavement by VMT/ Remainder by ESALs
II. Bridge Construction	
Preliminary & Construction Engineering	Basic Structure by VMT
Shoulder Construction	2 Increments
Lane Width	2 Increments
Bridge Construction	Basic Structure by VMT/ Remainder by Live Load Moment
III. Other Common Costs	
Safety Programs	VMT
Administrative	VMT
Planning & Research	VMT
Land Management	VMT
Capital Outlay on Buildings	VMT
Roadside Improvements	VMT
General Maintenance	VMT
Guardrail Replacement	VMT
IV. Other Vehicle Class Shared Costs	
Weighing Program	Truck VMT
Ferry	Personal Use Vehicle VMT

The traffic-related basis for designing pavement durability is the anticipated number of standard axle load repetitions over the design life of the pavement. Following current design theory, the passage of an axle of any given weight is translated into an equivalent number of passages of an axle weighing 18 kips (18,000 pounds). Thus, each axle is assigned an 18 kip equivalent single axle load value. Although the value varies depending on several pavement design parameters, ESALs are considered additive for any given pavement design. The number of anticipated cumulative ESALs is used as the traffic-related variable in pavement design.

The design-based approach most commonly used in cost allocation studies until recently is termed the incremental method. Here, the concept is to develop the costs of constructing a particular roadway for the smallest possible vehicle, all the costs of which would be considered jointly-occasioned costs. The costs of this minimum design would be allocated to all vehicles. Next, the additional or incremental costs to build the same road for the next larger type of vehicle, for example, a two-axle truck, would be determined, and that increment would be assigned to all trucks that are two-axle or larger. Each individual roadway section is redesigned and costed in terms of the amount of the additional thickness required for each successive increase in vehicle size. The approach hypothetically removes or adds vehicles while estimating the resulting reduction or increase in costs. The design and costing of the series of pavement thicknesses can be accomplished by either starting with a pavement that will accommodate all classes of vehicles in the traffic stream and redesigning the pavement each time a vehicle class is removed, or by starting with a minimum pavement and redesigning as vehicle classes are added.

There are substantial criticisms that can be leveled at the incremental method as traditionally applied. The method ignores the premise of roadway design theory and highway design practice in Virginia. Whether the stress placed on the road is caused by frequent small loads or occasional large loads does not matter. It is the total amount of stress placed on the road that is important. Using the incremental approach, costs are arbitrarily assigned because the order in which axle weights are removed from the traffic stream makes a tremendous difference in attributed costs. An anticipated ESAL removed from a thick pavement changes the thickness much less than one removed from a thin pavement and results in a corresponding discrepancy in assigning pavement cost. Choosing which ESALs to remove first is akin to making an à priori decision to skew cost responsibility by providing one class of vehicles with a benefit to which they may not be entitled. In addition, the boundary cutoffs are arbitrary. Within an increment, axles are charged equally regardless of how much weight is removed.

Economies of scale exist in pavement design which affect the distribution of costs for cost responsibility. Additional thickness needed decreases as the number of ESALs increases. Figure 5 presents an example of the relationship between thickness and ESALs using an incremental approach. In the example, adding "Increment 2" to the expected traffic mix increases pavement thickness by 50 percent through the addition of 27 ESALs, but adding "Increment 6" requires only a 25 percent increase in pavement thickness even though 278 ESALs are added. From a cost-occasioning standpoint, economies of scale are produced by the incremental methodology and there is no technical reason to award the benefits to any vehicle class.

Minimum Thickness Approach (Uniform ESAL Method)

The state-of-the-art was advanced with the development of the uniform method used for the 1982 Federal Cost Allocation Study. In this approach, all costs beyond the minimum thickness are allocated based directly on ESALs. ESALs are applied and randomly removed such that no vehicle class benefits unfairly from any economies of scale. Since increments are not used, the method specifically addresses the shortcomings of the other method. All costs between the full thickness and the basic thickness are allocated and no vehicle classes are favored. The cost of the basic (minimum) thickness is shared by all vehicles, based on expected VMT. Because the method closely follows actual pavement design practice, it is the best of the methods available to attribute costs. Since its development, most states have used this approach.

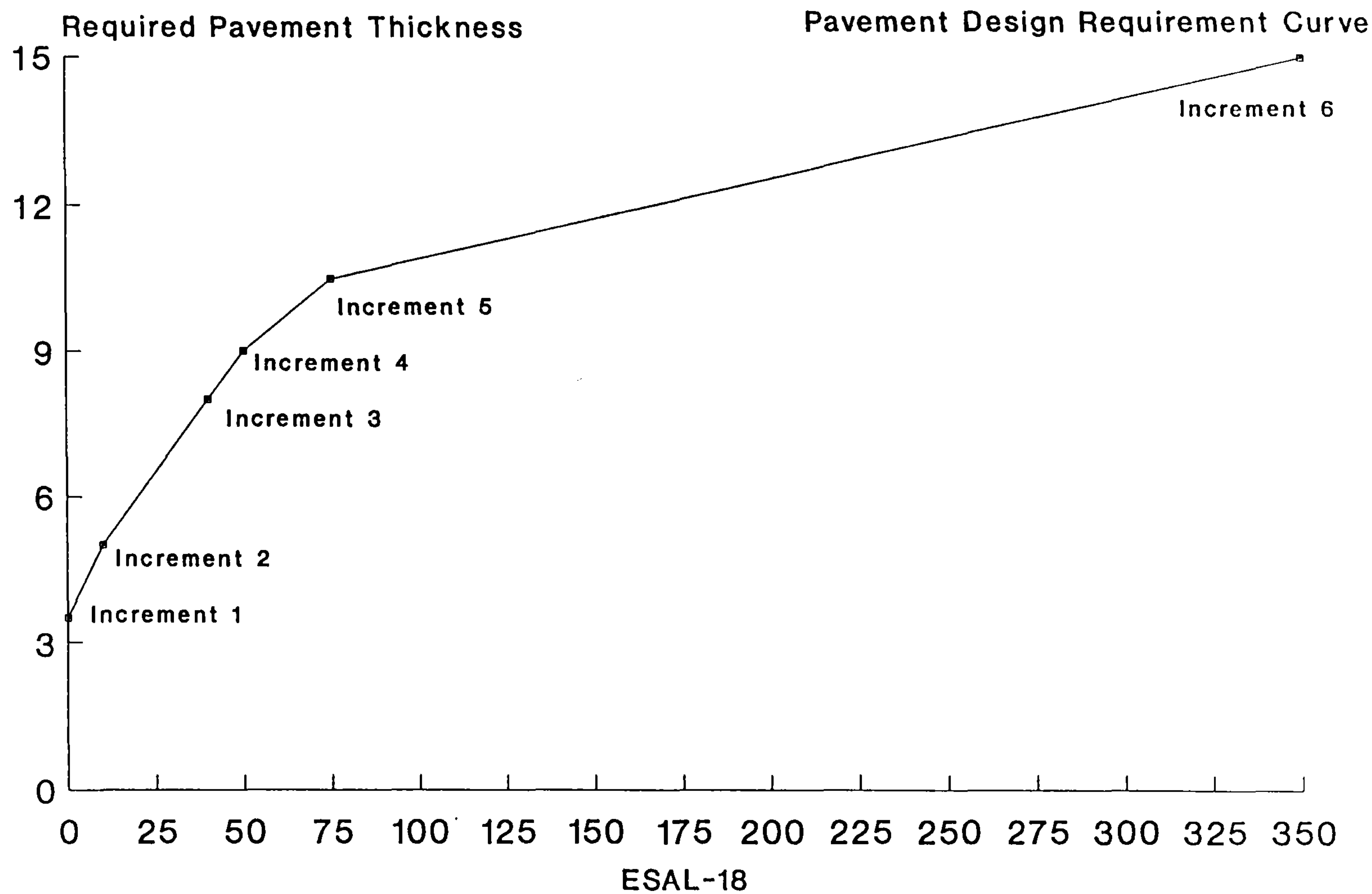
Roadway Project Selection

The design, reconstruction and rehabilitation of pavements are based on the level of traffic, in particular the number of ESALs, operating over each segment. It would not be appropriate to average costs across the Commonwealth because of the nonlinear relationship between axle load and pavement wear. Designing for 40,000 ESALs is not twice as costly as designing for 20,000 ESALs. Construction and resurfacing costs must, therefore, be developed at the individual project level and aggregated.

It was important to consider a full range of construction projects in order to represent the types of work that occur in the Commonwealth, now and in the near future. Administrative systems were analyzed separately to account for the differences in design for the system types and to ensure geographical balance as well as diversity in project cost, size, and nature of construction. All completed projects identified in the Bid Analysis and Monitoring

FIGURE 5

EXAMPLE OF ECONOMIES OF SCALE INHERENT IN PAVEMENT DESIGN



System (BAMS) data base (begun during fiscal year 1986 and completed by June 1990) were included in the population of projects. This resulted in 1,122 projects, not all of which were pavement construction. The projects retained included construction, paving, and incidental construction.

Since it was impossible to analyze all projects, a sample was chosen for each administrative system based on design parameters. Pavement design varies by the region or climatic zone, and the expected daily ESALs. The cost also varies by virtue of the number of lanes and differences in lane width. Variables used to stratify the population of projects were administrative system, soil support value, and climate factor. These variables were chosen to ensure variation in project type and location and to serve as indicators of cost. Soil support is an index of foundation strength, and climate factor provides an indication of climate severity as assigned by the National Weather Service. Climate provides reasonable geographic distribution while foundation strength is a direct input to pavement design. Analysis of the sampled projects indicated they were statistically representative of the population of projects.

The roadway costs to be allocated were composed of: 1) minimum or basic pavement costs required to construct a pavement thick enough to carry the smallest of vehicles, which in this study was a car; 2) costs associated with construction of the road to carry the remaining vehicles; 3) costs related to construction of pavements wide enough to carry the larger vehicles; and 4) costs of the ancillary activities associated with constructing roads such as preliminary engineering, construction engineering, and right-of-way acquisition.

New Pavement Construction

Traffic Evaluation

Pavement construction costs are considered to be vehicle weight and volume related and to be occasioned costs. The thickness of each pavement is a function of an anticipated number of standard axle load repetitions over the design life of the pavement.

In practice, an ESAL usually is defined as prescribed by the American Association of State Highway and Transportation Officials (AASHTO). Special loadometer studies are conducted to estimate the number of ESALs to be expected for the design life. Then, equations derived from the performance of in-service pavements are used to relate the projected ESALs to a design thickness index or structural number (standard measures of pavement strength).

Design Approach

For the purpose of examining cost responsibility, pavement costs were assigned based on current pavement design practices. In Virginia, rigid pavements are considered for only the heaviest traffic corridors where they may be economically competitive. In view of the relatively few rigid pavements in the total Virginia system (less than one percent of the mileage), the pavement construction cost analyses assumed that only flexible pavements were constructed. Where major rigid pavement projects were constructed the projects were redesigned as flexible pavements and the costs allocated accordingly.

For the thickness determination of flexible pavements, Equation 1 was used. Developed from the AASHTO approach, it was applied to Virginia environments, soils, and materials. In this equation, used for some 20 years in Virginia, the principal parameters are average daily ESALs in the design lane over a 30-year design life, the California Bearing Ratio (CBR) and a regional factor (R) depending upon location within the State.

$$TI=\frac{5.77\,(ESAL)^{0.189}}{(CBR*R)^{0.147}} \tag{1}$$

These parameters characterize traffic, foundation soils, and environmental inputs to the pavement design process. The thickness index (TI) is a normalizing index expressing pavement strength as an equivalent thickness of asphaltic concrete. While the above equation is applicable only to the heavier pavements used in the State, a similar equation from Virginia design standards is used for the secondary system. This latter equation results in the definition of two different minimum pavements (see below) depending upon the administrative system under consideration.

Minimum Pavements

Inasmuch as there are construction limitations on how thin a pavement can be built, most cost responsibility studies provide for a minimum or base pavement which is allocated to all vehicle classes as a joint cost. In the case of pavements built in Virginia and of materials typically found in Virginia, two minimum pavements are used. While both have six-inch thick base layers comprised of crushed stone, one typically used on low volume (less than 1,000 vehicles per day) secondary roads is surfaced with a prime and double seal of approximately one-half inch thickness. A second, for all higher types of roads (primary and interstate as well as high traffic volume secondary roads) is surfaced with one and one-half inches of asphaltic concrete.

Pavement Thickness Above the Minimum

Cost of pavement thickness above the minimum constructible is an occasioned cost and is allocated to each vehicle class in proportion to its responsibility for the additional thickness. The project traffic data existed only for five vehicle classes: passenger vehicles, buses, four-axle six-tire trucks, single units and combination vehicles. Therefore, occasioned costs were initially allocated at the project level to these five classes.

Pavement Width Allocation

The costs of pavement width beyond the minimum necessary for the narrowest vehicles were assigned to wider vehicles in proportion to their representation in the traffic stream and in proportion to their ESAL contributions. Only the extra-strength portion of the additional width is attributed by ESALs. Thus, if 50 percent of pavement thickness discussed earlier is attributable to ESALs, then 50 percent of the additional width would be assignable on the basis of ESALs, but only to vehicles in those classes causing the need for additional width. The minimum thickness portion of the additional width is allocated to those same vehicles on the basis of their average daily traffic.

On primary and interstate highways only 11- and 12-foot-wide lanes are constructed and, in general, the width up to ten feet is required by all vehicles. Only that portion of the width greater than ten feet would be assignable to trucks and buses having maximum widths of 96 to 102 inches. On secondary roads, narrower lane widths typically are used and were reflected in the analysis.

Summary of New Pavement Construction Allocation

To summarize, for a given project, the allocation process for new pavement construction costs is as follows (The reader should note that the full study involves the aggregation of the results of hundreds of such analyses for each administrative class.):

1. The thicknesses and types of pavement layers are determined from project design and construction records.

2. Vehicle traffic data are determined from traffic records for the project traffic stream.

3. a. The responsibility for all pavement over the minimum thickness is allocated to vehicle classes in proportion to the ESALs generated by the classes.

   b. For the minimum pavement:

      The first ten feet of width is allocated to all vehicles on the basis of ADT.

      All widths over ten feet are allocated to buses and larger vehicles on the basis of the ADT of those vehicles.

4. The allocation of pavement construction costs to vehicle classes is straight-forward once the pavement geometry, traffic stream, and cost data are available. Briefly, the ESAL occasioned costs (the pavement beyond the minimum) are allocated to the classes in proportion to the ESAL contribution of each class. The minimum pavement costs are allocated in proportion to the ADT contribution of each class, and the widening costs are allocated as discussed above.

The allocation process is basically as discussed above. However, some minor differences in allocation procedures were required due to the differences in administrative class. Allocations on the secondary system differed from the other two classes due to the design parameters of the road. Generally, narrow, two lane roads are found on this system. The result is that there is no pavement width to be allocated beyond the standard design. Another feature found only on this class of roads is the occasional occurrence of traffic streams requiring less than the minimum pavement. In such cases all paving expenditures were allocated on the basis of ADT rather than ESALs.

Pavement Surface Repair and Rehabilitative Costs

Most pavement engineers would agree that the principal causes of pavement deterioration are the destructive effects of vehicle loadings and of weathering. The relative weights of these causes are difficult to assess because of inherent uncertainties in pavement design. Variability in highway materials and differences in the construction processes cause pavements to perform either better or worse than would be predicted.

In most cost responsibility studies, it is argued that pavement deterioration is related to ESALs in much the same manner as are pavement thickness designs. Therefore, the most frequently used assignment of pavement surface repair and rehabilitation costs is to attribute those costs to ESALs in the same proportion as new pavement construction costs.

As discussed in the methodology report for the present study, the study team explored the possibility of allocating pavement rehabilitation costs according to empirical relationships between pavement deterioration and the accumulated ESALs at the time that deterioration was measured. These efforts generally were unsuccessful. While there were statistically significant relationships between accumulated ESALs and pavement deterioration, the relationships did not have sufficient predictive capability to be used.

Pavement rehabilitation costs were, therefore, allocated as given in the discussion of new pavement thickness. Thus, the pavement surface repair and maintenance replacement expenditures for the base year for each administrative class are allocated to vehicle classes in the same proportions as that described in the sections above.

Other Roadway Costs

Roadway Engineering and Right-of-Way Costs

This group of costs relates to the planning and designing of roads and the acquisition of right-of-way. Some of these costs may be attributable to large vehicles, inasmuch as designing a thicker pavement is more complex than a thin pavement and more right-of-way is used for wider roads. However, it was not obvious how much should be attributed in that manner and therefore, all such costs were allocated to all vehicles.

The engineering, design, and right-of-way costs are necessary to the construction of even the minimum pavement and are therefore attributed in the same manner. The costs were allocated in relation to the vehicle miles traveled by the vehicle types for each project, based on the project average daily traffic.

Roadway Grading Costs

Grading costs were allocated using a methodology described by Leisch[6] where costs were assigned to vehicles necessitating the grading. Theoretically, grades could be steeper if vehicles had more power and better climbing and stopping abilities. Therefore,

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6 Synthesis of Information on Roadway Geometrics Causal Factors., Jack E. Leisch and Associates, Evanston, Illinois, January 1981.

wherever natural grades of terrain are steeper than allowable road grades, costs could be saved if the heavier vehicles could be removed from the traffic stream. Grading costs are assigned to these vehicles incrementally, based on the weight and the horsepower rating of these vehicles, and whether the terrain is rolling or mountainous.

Cost savings in each terrain type were estimated based on the Leisch formula. Proportional savings in earthwork, as a function of maximum allowable grade, were determined by the function:

$$C=1-k((400-W_p)/300^{1.45}) \quad (for\ 100\leq W_p\leq 400) \tag{2}$$

where

C = proportion of grading costs compared to those incurred for the most demanding vehicles

k = a constant, varying from 0.105 for Interstate highways in rolling terrain to 0.59 for collectors in mountainous terrain

Wp = pounds per horsepower of the design vehicle [7]

The allocation of grading costs used the VMT distributions for the weight categories of each administrative system and horsepower ratings taken from the 1982 Truck Inventory and Use Survey[8] issued by the U.S. Census Bureau. Truck weight and horsepower data were input into the Leisch formula, which yielded the incremental proportions of grading costs for each vehicle weight/horsepower combination and type of terrain. Incremental costs were allocated to the vehicle classes based on the VMT tables.

Summary of Roadway Costs

Roadway construction costs are composed of pavement construction, preliminary engineering (PE), construction engineering (CE), right-of-way (ROW), grading, and other

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[7] Ibid, p. 5.

[8] Truck Inventory and Use Survey., Washington, D.C.: U.S. Bureau of Census, 1982.

construction. Once roadway costs were attained for the five vehicle classes for each administrative system using project ADT, cost allocations for the nine vehicle classes were developed. The five vehicle classes were expanded to nine classes using statewide VMT for each administrative system.

Table 6 displays new construction roadway costs in terms of the basic costs for the minimum pavement, the occasioned pavement costs attributed to vehicles by virtue of their dimensions, and the other roadway construction costs including preliminary and construction engineering, right-of-way, and miscellaneous costs. Total pavement construction costs amounted to 41.6 percent of total roadway construction costs.

TABLE 6

Breakdown of Roadway Costs
For New Construction
(in Percents)

Minimum Pavement	Occasioned Pavement			Other Roadway
	Thickness	Width	Total	PE+CE+ROW+Other
14.9	22.6	4.1	26.7	58.4

The relative proportion of the minimum pavement construction costs vis-a-vis total pavement construction costs (35.8 percent) is relatively low but similar to other studies. When compared with all roadway costs, the amount directly related to vehicle dimensions (26.7 percent) is even smaller. As a result, the majority of roadway costs are attributable to vehicles with high VMT. Table 7 further demonstrates this fact; of the total roadway costs, 65 percent is attributed to personal use vehicles, two percent to buses, seven percent to light trucks (two-axle six-tire trucks), three percent to single units and 22 percent to combinations.

Roadway cost allocations displayed in Table 7 are for the full nine vehicle classes and for five weight groups. Within the five- and six-axle tractor semitrailer class, one sees a bimodal distribution, with 36 percent of the costs attributed to those vehicles operating over 70,000 pounds. Also, nearly 20 percent of costs are attributed to multitrailer trucks at that weight. Within truck classes, the largest share of both total roadway costs and costs for operating over 70,000 pounds is attributed to the five- and six-axle tractor semitrailers.

BRIDGE COST ALLOCATION

The cost responsibility of the vehicle classes for structures was estimated using a design-based incremental approach. Bridge design differs from pavement design in that most of the costs are related to capacity (i.e., the number and width of lanes) and strength (the size of the supporting members). The strength is required to support the weight of the bridge itself, commonly called its dead load, and vehicles crossing the bridge, the live load. In the present study, costs were attributed to the various classes and weights of vehicles on the basis of the design strength required to accommodate their portion of both dead and live load. The costs associated with lane width requirements were attributed to larger vehicles. Costs for both new and replacement structures were allocated in the same manner.

The methodology for bridge cost allocation has been refined since the 1981 Virginia cost responsibility study. The current methodology is based on that developed for earlier studies performed by FHWA and subsequently adopted by other state transportation agencies.

Bridge Cost Allocation Methodology

The methodology developed for the 1982 Federal Cost Allocation Study and expanded in the 1988 Heavy Vehicle Cost Responsibility Study was based on the Incremental Analysis of Structural Construction Cost performed by Sinclair and Associates.[9] Sinclair identified 12 prototype bridges which represented common types of structures in the National Bridge Inventory (NBI) and which encompassed a full range of span lengths. For each of the prototype bridges, Sinclair designed eight hypothetical bridges for seven decreasing design loads. The design loads included 72 kip and 54 kip combinations and 40, 30, 20, 10 and 5 kip single-unit vehicles. These corresponded to AASHTO's standards for HS20, HS15, H20, H15, H10, H5, and H2.5 design vehicles. The eighth hypothetical design utilized the lightest loading in conjunction with a reduced width to determine the proportion of the costs attributable to the width required for large trucks. Using standardized unit costs for materials derived from detailed plans

[9] Sinclair, Benito A. & Associates, Inc., Incremental Analysis of Structural Construction Costs., U.S. Department of Transportation, Washington, D.C., April 1981

TABLE 7

Roadway Costs by Weight Group
Percent By Class

WEIGHT	CAR/CYCLE	2A4T	BUS	2A6T	3ASU	4+ASU	4-AST	5+AST	5+AMT	TOTAL
< 10k	100.00	97.52	0.00	27.77	0.31	5.17	0.39	0.00	0.00	66.93
10-30k	0.00	2.48	63.64	70.33	64.70	10.34	48.03	8.62	1.15	11.45
30-50k	0.00	0.00	36.36	1.90	27.68	5.17	47.64	32.62	24.08	9.16
50-70k	0.00	0.00	0.00	0.00	5.91	62.07	3.94	22.61	55.04	5.10
>70k	0.00	0.00	0.00	0.00	1.40	17.24	0.00	36.14	19.73	7.35
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total By Type	49.75	15.46	2.18	7.49	2.76	0.27	1.82	19.92	0.35	100.00

for the prototype bridges, costs were determined for each hypothetical design.

The 1988 study refined the approach by relating the live-load moment produced by each vehicle to the cost requirements, thus defining a continuous cost function. A cost was then obtained for every vehicle class at every weight group for each prototype bridge on the basis of the moment produced. Shares of the cost for each bridge type were derived for each vehicle and weight group based on VMT and the assigned responsibilities of the vehicle class. Expenditures for each bridge type were determined and the cost for each vehicle at each weight derived by multiplying the cost share factor for the vehicle class by the dollars spent on the corresponding type of bridge. The cost responsibility was, therefore, weighted by expenditure rather than number of bridges.

The application of the 1988 methodology to the Virginia Cost Responsibility Study will be discussed in more detail in subsequent sections of this report.

Selection of Bridges

Sinclair's prototype structures are listed in Table 8. The types of structures were found representative of those built in Virginia from fiscal year 1979-80 through fiscal year 1988-89, if short steel girder spans were substituted for long prestressed concrete box girder spans that were included in the original sample. None of the latter structure had been constructed in Virginia during that ten-year period. With the substitution, the prototype structures represented 88 percent of the 10-year population. Similar results were obtained when the prototype bridges were compared with the types of structures built in fiscal years 1987, 1988 and 1989, and with those in the entire state inventory.

On the basis of these comparisons, Sinclair's relative cost data and width cost data were accepted for use, and corresponding data were developed for the short steel girder span.

Development of Cost/Moment Relationship

Maximum live-load moments were calculated for each sample bridge for each of the design loads and for every vehicle class at every weight group included in the study. A regression model (Equation 3) was used to estimate the costs.

TABLE 8

Sample and Population of Bridges Used for
Bridge Capacity Cost Analysis

Type of Bridge (Design-NBI Code)	Main Span Range *	Percent of Virginia Bridges: Statewide System	Last 10 Years	FY87-89
Concrete Slab (Simple-101)	Short	21.4	17.4	15.6
Concrete Slab (Continuous-201)	Short	1.0	0.9	0.8
Concrete T-beam (Simple-104)	Short	8.4	6.7	7.4
Concrete Girder (Simple-102)	Short	0.6	0.2	0.2
Prestressed Concrete Girder (Simple-502)	Medium	2.7	3.5	5.8
Prestressed Concrete Girder (Continuous-602)	Medium	0.1	0.3	0.8
Prestress Concrete Multicelled Box Girder (Simple-505)	Medium	0.6	1.4	1.0
**Steel Girder (Simple-302)	Short	33.3	23.2	20.8
Steel Girder (Simple-302)	Medium	15.0	19.4	18.8
Steel Girder (Simple-302)	Long	3.0	5.8	5.3
Steel Girder (Continuous-402)	Medium	2.1	3.6	4.6
Steel Girder (Continuous-402)	Long	2.3	5.6	6.9
Other		9.5	12.0	12.0
		100.0%	100.0%	100.0%

* Range -- short -- spans less than 50 feet
medium -- spans between 50 feet and 100 feet
long -- spans greater than 100 feet

** Steel girder spans (Simple -- less than 50 feet) replaced prestressed concrete multicelled box girder spans (simple -- long range) used in federal studies.

$$y = a + bx \quad (3)$$

where:

y = bridge cost for each vehicle

a = the constant term

b = the coefficient which estimates the relation between live-load moment and cost

x = the live-load moment produced by the vehicle

Regression analyses using the live-load moments produced by the seven design loads and relative cost data developed by Sinclair and VDOT for the 12 sample bridges provided the estimates for "a" and "b" in Equation 3. The estimates of these values and the calculated moments for the study vehicles at each weight class provided the cost data for a matrix relating costs to every vehicle class and weight group for each sample structure. Shares of the cost for each sample bridge were then derived for each vehicle and weight group using an incremental approach. All vehicles shared the minimum structure cost on the basis of VMT. Costs beyond the minimum were distributed on the basis of the VMT and incremental cost occasioned by the particular vehicle class/weight group combination. The total of the minimum and incremental cost for each vehicle class/weight group combination determined its cost share factor. The cost shares were used to apportion the expenditures for each bridge type to each vehicle at each weight group.

Bridge Width Costs

The required width of an individual traffic lane is a function of the type of traffic expected on the bridge. It is logical that a hypothetical structure designed to carry only cars and light trucks could be narrower than those designed to common standards. To allocate the costs of the additional width, each of the prototype bridges was designed for narrow lanes using the light (five kip) loading. Sinclair's calculations of the variation of cost with deck width suggested that width costs as a proportion of total bridge costs for the sample bridges ranged from nine percent to 17 percent in all cases. Table 9 reports the proportions of costs attributable to lane and shoulder width requirements. These proportions of the allocations for each of the 12 sample bridges were assigned to buses and three-axle or larger trucks on the basis of VMT.

TABLE 9

Proportion of Bridge Costs for Each Bridge Type
Attributable to Width Requirements

Type of Bridge	Costs Attributable to Width Percent
Concrete Slab	16.51
Continuous Concrete Slab	12.08
Concrete T-beam	10.91
Concrete Girder	14.71
Prestressed Concrete Girder	16.77
Continuous Prestressed Concrete Girder	15.49
Prestressed Concrete Multicelled Box Girder	15.28
Steel Girder (short)	14.48
Steel Girder (medium)	16.88
Steel Girder (long)	13.68
Continuous Steel Girder (medium)	8.90
Continuous Steel Girder (long)	16.87

Note: These proportions are based on the work of Sinclair except for those calculated for the steel girder (short) and the continuous steel girder (long).

Allocation of Expenditures to Bridge Types

Data on expenditures for each of the 12 sample bridges for the three fiscal years in the study period were obtained from BAMS. As its name implies, BAMS is intended to be a tool for the analysis of bids received for advertised projects. It is, however, considered an accurate reflection of construction costs for those projects that are included.

A thorough comparison was made of those structures in BAMS and those entered in the more complete bridge inventory system during the three study years. Costs from BAMS for each of the sample bridges were extrapolated to represent the larger number of bridges in the inventory. The expenditures were then totalled and the percent expenditure for each bridge type was calculated. Finally, the percentages were applied to the total allocation for structures during the study period, standardized to 1989 dollars, to determine the expenditures for each bridge type.

Replacement, Rehabilitation and Repair of Bridges

In a review of the 1981 Virginia Cost Responsibility Study, it was suggested that the remaining capacity of a deficient bridge be determined and a greater portion of the cost of the replacement structure be allocated to vehicles heavier than that capacity. The federal studies did determine load deficiency costs by prorating replacement costs by the relative importance of load deficiency in the decision to replace the bridge. However, the proportion of bridge costs that was attributable to load deficiencies was only approximately 3.5 percent. Because of the small contribution to bridge costs, the complexity of the analysis, the difficulty in differentiating replacement construction and in ascertaining the influence of load carrying capacity in the replacement decision, it was not considered practical to attempt this analysis. It is hoped that the improved bridge management system now being developed will provide the needed data for future studies.

General Bridge Maintenance Costs

Costs in these categories were considered common costs and were distributed to all vehicles by VMT.

Engineering Costs

Preliminary and construction engineering costs for structures were allocated by VMT.

Summary of Bridge Costs

Upon the determination of the expenditures for each bridge type, the width cost was distributed to buses and three-axle and larger trucks on the basis of VMT.

The remaining expenditures, the basic bridge costs, were distributed to every vehicle class and weight group using the cost share factors for each bridge.

Finally, the width costs and basic costs for the 12 sample bridges were totalled for every vehicle class and weight group and combined to yield the total costs by weight group shown in Table 10.

Of the bridge costs, 60.0 percent were attributed to personal use vehicles, with the next largest share assigned to combinations (23.6 percent). Single-unit trucks were responsible for 10.9 percent of the costs, while buses accounted for 3.0 percent and light trucks, 2.6 percent of the costs.

TABLE 10

Bridge Costs by Weight Group
Percent By Class

WEIGHT	CAR/CYCLE	2A4T	BUS	2A6T	3ASU	4+ASU	4-AST	5+AST	5+AMT	TOTAL
< 10k	100.00	96.49	0.00	19.52	0.16	0.18	0.35	0.00	0.00	60.09
10-30k	0.00	3.51	56.01	76.22	38.67	0.44	45.26	5.12	0.20	7.49
30-50k	0.00	0.00	43.99	4.26	21.75	0.32	49.42	21.69	5.27	7.57
50-70k	0.00	0.00	0.00	0.00	7.90	7.89	4.97	19.42	22.34	5.33
>70k	0.00	0.00	0.00	0.00	31.52	91.17	0.00	53.76	72.19	19.52
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total By Type	46.65	13.39	2.95	2.58	4.72	6.16	1.06	20.78	1.72	100.00

DRAINAGE COST ALLOCATION

Drainage structures, including box culverts and pipes of various sizes, constitute a significant portion of the highway investment. Small culvert pipes are specified in accordance with fill-height tables, regardless of vehicle characteristics. Box culverts are designed in a more comprehensive manner, and experience indicates that vehicle characteristics are important if the fill height above the structure is less than ten feet.

Accordingly, expenditures for minor drainage structures were treated as common costs associated with the roadway. The major structures, those with assigned project numbers, were generally found to be box culverts with less than ten feet of fill. The structural behavior of box culverts approximates that of a continuous slab, thus the cost share and width cost factors developed for continuous concrete slab bridges were used.

Sixty-six percent of the drainage costs were attributed to personal-use vehicles with the next largest share assigned to five- and six-axle trucks. Single-unit trucks were responsible for ten percent of the costs, and two-axle, six-tire vehicles and buses were each responsible for three percent of the costs.

COMMON COST ALLOCATION

Common costs are jointly-occasioned costs that are assigned to all highway users. They are comprised of costs that are not attributable to vehicles based on any characteristic of the vehicle itself. Since common costs are not caused by particular vehicle attributes, another methodology must be used to allocate these costs. It is assumed that facilities and services are made necessary by the need for travel and are consumed regardless of the type of vehicle operating on the roadway. The quantity of such services is assumed to vary based on the amount of travel. Accordingly, VMT was used to allocate common costs.

Items such as safety programs, administration, general maintenance, planning, and research are costs that are not specific to vehicle type. In addition, there are generic costs that are assignable to broad classes of vehicles, but not by virtue of the weight or size of a vehicle. For example, the ferry is allocated to passenger vehicles, while truck scales are allocated to trucks. There are, therefore, two types of costs that are not weight or size-related: those common to all vehicle types, and those common to particular vehicle types. These latter group of costs, termed vehicle-shared costs, reflect those programmatic activities that benefit only a few vehicle classes.

Common costs reported in Table 11 accounted for 27.4 percent of total allocated costs. Cars and two-axle, four-tire trucks account for the largest portion of common costs (90.0 percent), followed by tractor trailers (5.1 percent), two-axle, six-tire trucks (3.1 percent), three- and four-axle single-unit trucks (1.1 percent), and buses (0.8 percent).

TOTAL COSTS

The total of all cost responsibilities by vehicle class is presented in Table 12. The majority are attributed to personal use vehicles (71.1 percent) with the next highest responsibility attributed to five or more axle tractor semitrailers (15.8 percent). Three- and four-axle vehicles have little overall cost responsibility (5.3 percent) but the effect of heavy axle weight can be observed in the proportion of four-axle, single-unit costs attributed to those vehicles operating over 70,000 pounds. The fact that so few operate at that weight keeps the share of the vehicle class relatively small.

The effect of the higher weights can be seen for the multiple trailer units and also for the five- and six-axle combination vehicles. As the VMT of the multiple trailers increase over time, it is to be expected that their relative share will also increase.

The costs are presented in terms of operating weights. The attribution of costs is thus accurate for the class but a particular truck's cost responsibility would be determined based on cumulating the costs over its entire distribution of operating weights. In order to determine a particular truck responsibility or the responsibility of a group of trucks registered at a particular weight, one would need to understand the relationship between operating and registered weight and to have the distribution of operating weights for each registered weight class.

TABLE 11

Common Costs by Weight Group
Percent By Class

WEIGHT	CAR/CYCLE	2A4T	BUS	2A6T	3ASU	4+ASU	4-AST	5+AST	5+AMT	TOTAL
< 10k	100.00	97.52	0.00	27.77	0.31	5.17	0.39	0.00	0.00	90.34
10-30k	0.00	2.48	63.64	70.33	64.70	10.34	48.03	8.62	1.15	4.42
30-50k	0.00	0.00	36.36	1.90	27.68	5.17	47.64	32.62	24.08	2.32
50-70k	0.00	0.00	0.00	0.00	5.91	62.07	3.94	22.61	55.04	1.22
>70k	0.00	0.00	0.00	0.00	1.40	17.24	0.00	36.14	19.73	1.70
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total By Type	69.99	19.96	0.79	3.12	1.00	0.09	0.38	4.57	0.11	100.00

TABLE 12

Total Costs by Weight Group
Percent By Class

WEIGHT	CAR/CYCLE	2A4T	BUS	2A6T	3ASU	4+ASU	4-AST	5+AST	5+AMT	TOTAL
< 10k	100.00	97.35	0.00	26.99	0.26	0.82	0.39	0.00	0.00	72.09
10-30k	0.00	2.65	61.26	70.89	55.26	1.70	47.58	7.74	0.59	8.74
30-50k	0.00	0.00	38.74	2.12	25.44	0.94	47.93	29.86	12.97	6.97
50-70k	0.00	0.00	0.00	0.00	6.59	14.79	4.11	21.80	35.77	4.07
>70k	0.00	0.00	0.00	0.00	12.45	81.75	0.00	40.60	50.67	8.13
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total By Type	54.75	16.31	1.95	5.33	2.68	1.34	1.28	15.84	0.53	100.00

REVENUE ATTRIBUTION

Once cost responsibility for each vehicle class has been determined, the revenues contributed by each must be estimated. This estimation requires identification of the sources of highway user payments that are deposited into the Highway Maintenance and Operating Fund (HMOF) and Transportation Trust Fund (TTF). Estimation techniques are then employed to attribute these revenues to the vehicle class that paid them. This section describes the manner in which highway user revenues flow into the HMOF and TTF, and presents an estimate of the revenue paid by each vehicle class using Virginia's network of highways.

DESCRIPTION OF THE HIGHWAY MAINTENANCE AND OPERATING FUND AND THE TRANSPORTATION TRUST FUND

Revenues, consisting of various state taxes and fees, such as fuels taxes, vehicle sales and use taxes, federal revenues, and miscellaneous taxes and fees, are deposited in the HMOF and TTF. These funds are used to finance transportation programs throughout the Commonwealth. Legislation enacted by the 1986 Special Session of the General Assembly created the TTF, which receives 85 percent of Special Session tax sources and is used for highway construction (see Figure 6). The HMOF receives various traditional sources of revenue from highway users to meet expenses incurred by highway maintenance and operations (see Figure 7). The TTF receives the state taxes and fees enacted by the 1986 Special Session, including a portion of the state retail sales tax, all of the road use taxes, most federal and local revenues, and any balance remaining from the HMOF after non-construction programs are funded.

All federal-aid dedicated to interstate construction flows to the TTF. The other highway construction programs are financed by 85 percent of the total deposits received by TTF (see Figure 8). The remaining 15 percent of deposits and their independently accrued interest earnings flow to the Mass Transit Fund (8.4 percent), the Commonwealth Port Fund (4.2 percent), and the Commonwealth Airport Fund (2.4 percent). Actual cash receipts collected by the HMOF and TTF equaled $1.778 billion in fiscal year 1989.

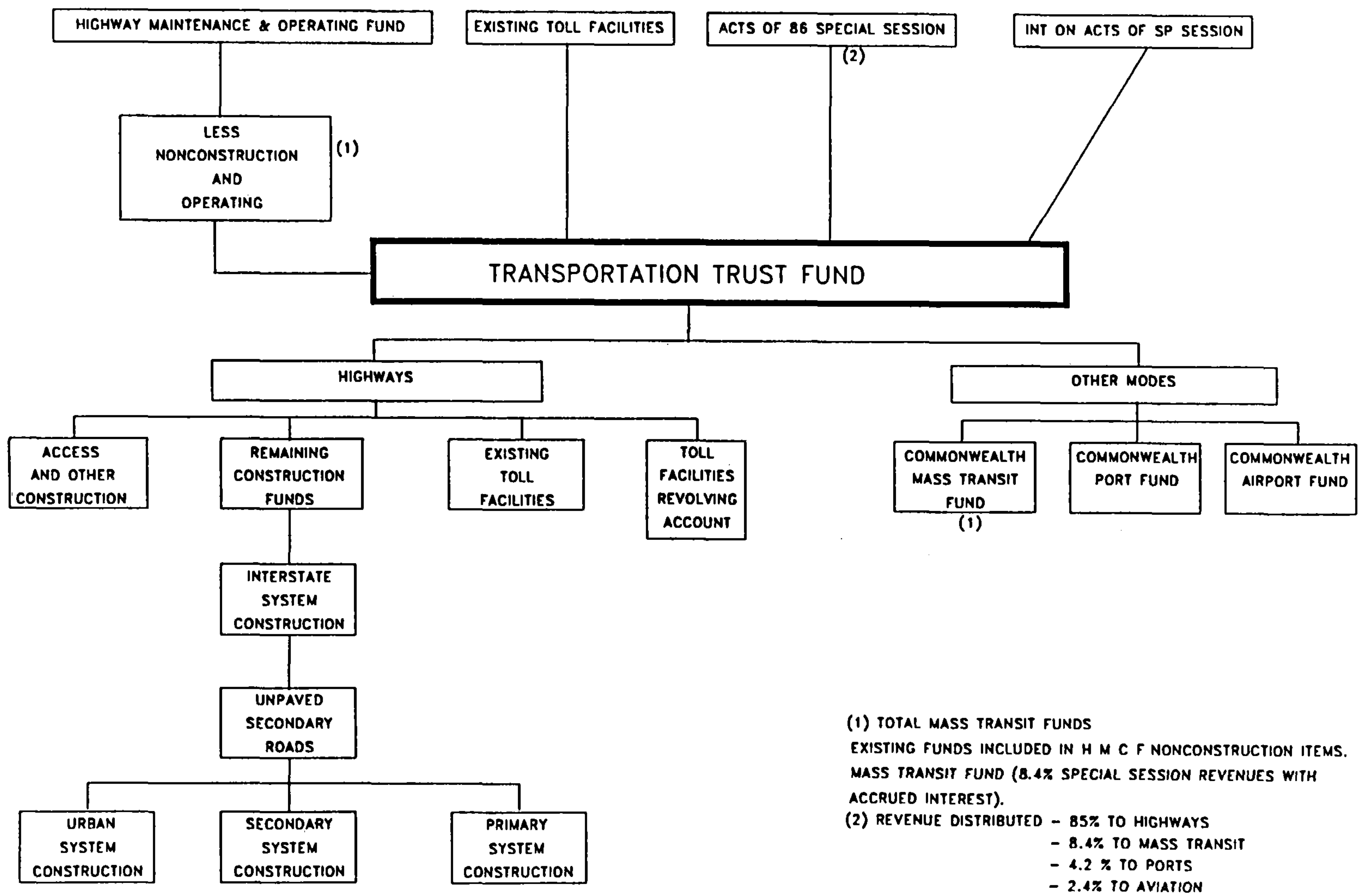
REVENUE ATTRIBUTION BASE

For the purposes of this study, revenues to be attributed to highway user classes are limited to those highway user taxes and fees that support the HMOF and the portion of the TTF dedicated to

FIGURE 6

TRANSPORTATION TRUST FUND DISTRIBUTION

FISCAL YEAR 1988 - 89



(1) TOTAL MASS TRANSIT FUNDS
EXISTING FUNDS INCLUDED IN H M C F NONCONSTRUCTION ITEMS.
MASS TRANSIT FUND (8.4% SPECIAL SESSION REVENUES WITH ACCRUED INTEREST).

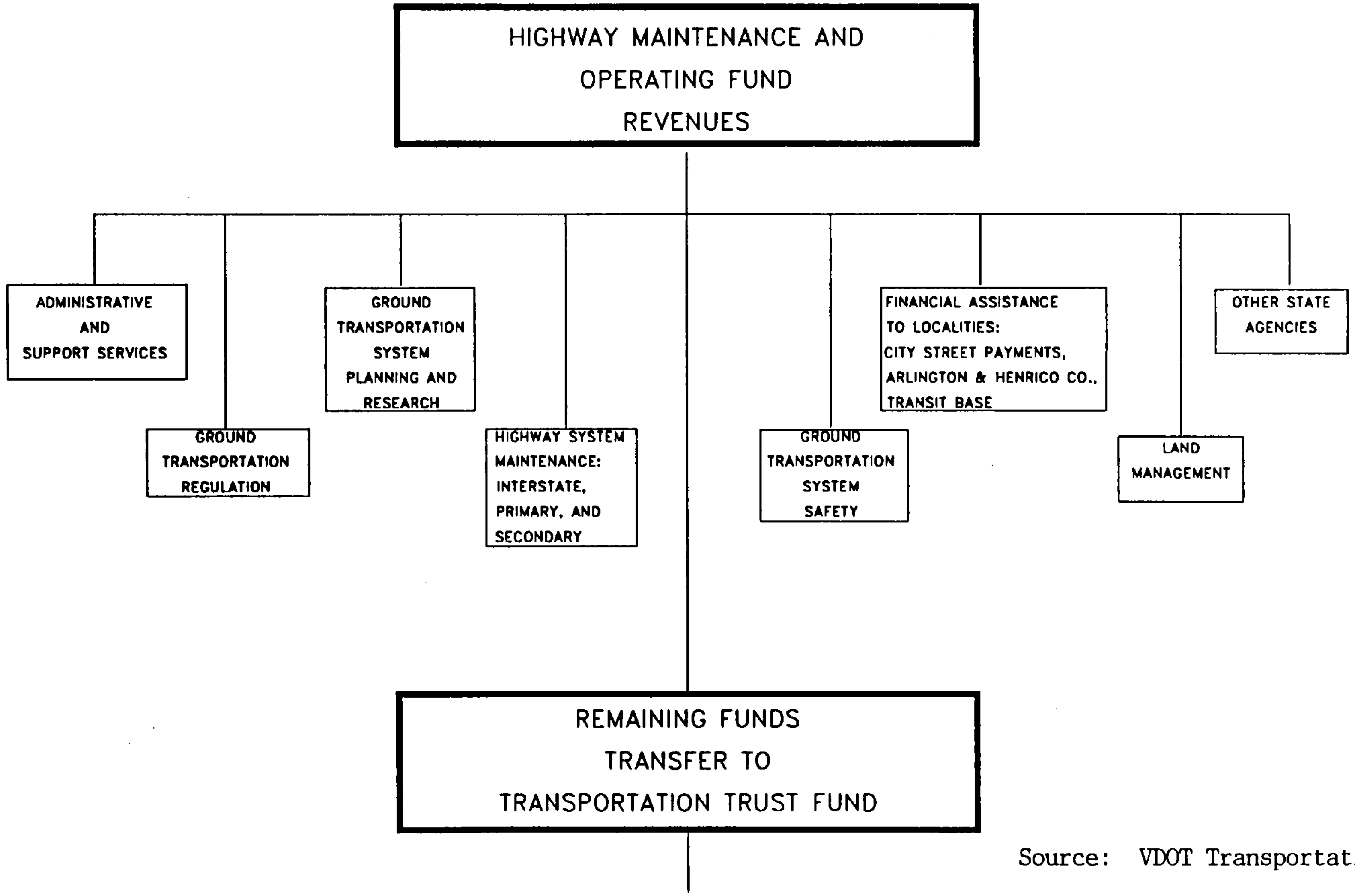
(2) REVENUE DISTRIBUTED - 85% TO HIGHWAYS
- 8.4% TO MASS TRANSIT
- 4.2 % TO PORTS
- 2.4% TO AVIATION

Source: VDOT Transportation Budget

FIGURE 7

HIGHWAY MAINTENANCE AND OPERATING FUND DISTRIBUTION

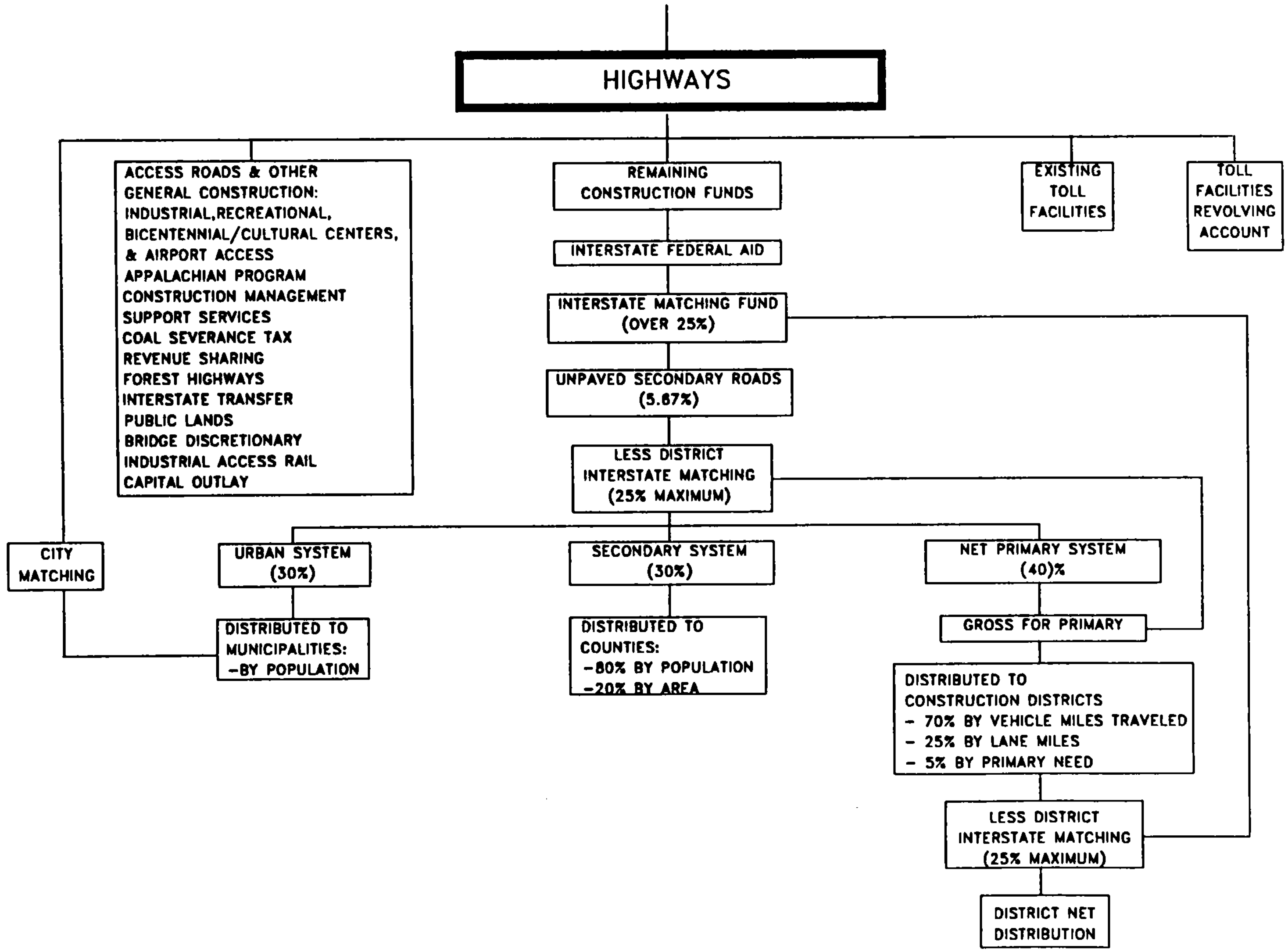
FISCAL YEAR 1988 - 89



Source: VDOT Transportation Budget

FIGURE 8

DISTRIBUTION OF HIGHWAY TRANSPORTATION TRUST FUND REVENUES
FISCAL YEAR 1988 - 89



Source: VDOT Transportation Budget

highway construction and maintenance. State and federal taxes and fees are presented in Appendix B. The major state user taxes and fees are as follows:

- state motor fuel, special fuel, and road use taxes,[10]
- state motor vehicle sales and use taxes,
- state license and registration fees[11] and permits,
- International Registration Plan (IRP) collections,
- ferry tolls,
- federal motor fuel and diesel fuel taxes,[12]
- federal retail tax (12 percent) on trucks, tractors and trailers,
- federal vehicle use tax on vehicles weighing more than 55,000 pounds, and
- federal excise tax on tires.

Several sources of revenue that flow through the HMOF and the TTF are not considered appropriate for attribution as user tax payments. These exclusions include certain fees that cover costs of service, and tolls dedicated to cover the construction, maintenance and operating expenses of specific toll facilities. Toll facilities are excluded from both the cost and revenue attribution because tolls are structured to cover the cost of such facilities over the long term. Those revenues excluded from attribution analysis are listed below:

- federal aid designated for non-highway purposes such as UMTA, Local Rail Continuance Assistance, and Appalachian Development,

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[10] The portion dedicated to the Leaking Underground Storage Fund is excluded from attribution ($.002). In addition, one percent of collections is dedicated to DMV for administrative costs and is therefore, excluded.

[11] Approximately 20 percent is dedicated to DMV and excluded from attribution.

[12] The portion dedicated to the Federal Transit Fund ($.01) is excluded as well as $.001 dedicated to the Federal Leaking Underground Storage Tank Trust Fund.

- o local government contributions such as the local match for urban allocations (particularly since legislation enacted in 1989 reduced these matches substantially), revenue sharing, and coal severance taxes,

- o the aviation fuel tax portion of special fuels taxes,

- o the portion of the three percent rental tax (2.5 percent) that reverts to localities,

- o toll revenues in support of specific facilities including the Powhite Parkway Extension, the Richmond-Petersburg Turnpike, the Norfolk-Virginia Beach Expressway, and the Dulles Toll Road. (It should be noted that while tolls on these facilities are excluded, motor fuels and special fuels taxes generated from toll facilities are attributed.),

- o revenues earmarked to DMV to cover administrative expenses. These revenues include one percent of motor fuel and special fuels taxes, and 20 percent of motor vehicle registration fees, and

- o liquidated damages for overweight motor vehicle violations.

The exclusions just noted represent approximately 7.5 percent of the total revenues that support highways. There remains, nevertheless, a major revenue source that is not a tax levied on users. This is the one-half percentage point of the state retail sales tax that is dedicated to transportation purposes. It generated approximately 12 percent of total transportation revenues in fiscal years 1988 and 1989 ($200 million in 1988 and $217 million in 1989). Some vehicle cost responsibility studies propose to attribute such general fund sources to the vehicle classes based on the number of vehicles in each class or on VMT. Such methods are subject to strong criticism, not only because they are arbitrary, but also because consumers, not highway users, pay the general sales tax. The Phase I Report of the Commission on Transportation in the Twenty-First Century (COT-21) clearly establishes the rationale for this revenue source.

> Highway user fees alone cannot produce that level of funding [necessary to fund the state's critical transportation needs]. A general tax increase is not only required, but it was determined to be appropriate

because of the essential role transportation plays in the economic growth of the Commonwealth.[13]

Later in this section, the general sales tax is compared to the amounts transferred to support other agencies, other transportation modes, and the user tax exemptions granted municipal and state government agencies for the operation of their vehicle fleets. Based on the premise set out in the Phase I report noted above, it may be appropriate to view the balance that remains as a benefit to each vehicle class from non-highway users.

Table 13 presents the total fiscal year 1988 and fiscal year 1989 state and federal revenue bases included in the revenue attribution analysis.

Table 14 shows the difference between total HMOF and TTF revenues and those taxes and fees included in the revenue attribution to users. The general sales tax, toll revenues, and receipts from cities and counties comprise 80 to 90 percent of the difference between total and attributable revenues each year.

STATE REVENUE ATTRIBUTION RESULTS

State revenues were attributed to the vehicle classes as shown in Tables 15, 16, and 17. Tables 15 and 16 present the results for fiscal year 1988 and fiscal year 1989, and Table 17 presents the average of the results for the entire analysis period in fiscal year 1989 dollars. Revenues were attributed using the estimation techniques described below. These techniques yielded estimates within 4.4 percent of fiscal year 1988 actual revenues, 0.45 percent of fiscal year 1989 actual revenues, and 2.9 percent of revenues over the two-year study period.

Motor Fuel, Special Fuels, and Road Use Taxes

The Commonwealth levies a fixed cents-per-gallon tax on fuel purchased within the State. Currently, the motor fuel tax equals 17.7 cents per gallon and the diesel fuel tax equals 16.2 cents per gallon. A portion of these taxes (0.2 cents per gallon) is specifically earmarked for the Virginia Leaking Underground Petroleum Storage Tank Fund. (In addition, one percent of fuel

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[13] Confronting Virginia's Transportation Challenge Phase I Report., The Commission on Transportation in the Twenty-First Century. Richmond, Virginia, 1986

TABLE 13

State and Federal Revenue Base by Source
Fiscal Year 1988 and Fiscal Year 1989
(in Millions of Dollars)

	Fiscal Year 1988		Fiscal Year 1989	
	Amount	Percent	Amount	Percent
State Source [a]				
Fuel & Road Use Tax	604.67	59.3	621.72	59.4
Vehicle Sales & Use [b]	269.63	26.4	264.40	25.2
Motor Vehicle License Fees	115.72	11.3	122.80	11.7
Permits [c]	5.52	0.5	5.46	0.5
International Reg. Plan	24.36	2.4	32.09	3.1
Ferry Tolls	0.50	0.1	0.50	0.1
Subtotal	1,020.40	100.0	1,046.97	100.0
Federal Source [d]				
Fuel Tax	283.04	82.0	329.99	84.2
Retail Sales Tax	36.22	10.5	35.54	9.1
Heavy Vehicle Use Tax	16.49	4.8	17.44	4.4
Excise Tax on Tires	9.39	2.7	9.04	2.3
Subtotal	345.14	100.0	392.01	100.0
Grand Total	1,365.54		1,438.98	

[a] Source: Commonwealth of Virginia, HMOF and TTF Statement of Revenue Estimates and Collections, August 1989; Commonwealth Accounting and Reporting System Reports #1673 (Net Revenue Fund Report).

[b] Includes 16.6 percent of rental tax.

[c] Includes overload, highway, and hauling permits plus transfers from the State Corporation Commission for motor carrier permits.

[d] Source: FHWA Highway Statistics, Table FE-9, 1988 and 1989.

TABLE 14

Total Transportation Fund Revenues vs. Attributable State and Federal Revenues -- Fiscal Year 1988 and Fiscal Year 1989 (in Millions of Dollars)

	Fiscal Year 1988	Fiscal Year 1989
Total Transportation Fund Revenues	1,738.5	1,778.9
Attributable Revenues	1,365.5	1,439.0
Difference	373.0	339.9

Source: VDOT Financial Reports, June 30, 1988 and 1989, Commonwealth Accounting and Reporting System, Net Revenue Fund Report, 1989, and Highway Maintenance and Operating Fund and Transportation Trust Fund Statement of Revenue Collections, 1988 and 1989.

TABLE 15

State Revenue Attribution by Class and Source -- Fiscal Year 1988 [a]
(In Millions of Dollars)

Class	Fuel & Road Tax	Sales & Use Tax	Licenses & Registrations	Permits	IRP	Ferry Tolls	Percent
Cars, motorcycles and pickups	487.46	249.48	85.72	0.00	0.00	0.50	80.7
Buses	1.79	0.22	0.12	0.00	0.00	0.00	0.2
2-axle, 6-tire trucks	22.11	8.76	10.41	0.00	1.82	0.00	4.2
3-axle or more single-unit trucks	12.59	2.46	6.25	0.28	2.33	0.00	2.3
Combination trucks	80.72	8.71	13.22	5.24	20.21	0.00	12.6
Total	604.67	269.63	115.72	5.52	24.36	0.50	100.0

[a] State Revenue Attribution is based on a methodology that yields $975.49 million in estimated attributable revenues. This is within 4.4 percent of actual revenues in categories defined for purposes of this study as attributable.

TABLE 16

State Revenue Attribution by Class and Source -- Fiscal Year 1989 [a]
(In Millions of Dollars)

Class	Fuel & Road Tax	Sales & Use Tax	Licenses & Registrations	Permits	IRP	Ferry Tolls	Percent
Cars, motorcycles and pickups	501.45	244.34	90.87	0.00	0.00	0.50	79.9
Buses	6.75	0.22	0.12	0.00	0.00	0.00	0.7
2-axle, 6-tire trucks	21.72	8.74	11.05	0.00	2.39	0.00	4.2
3-Axle or more single-unit trucks	15.27	2.48	6.73	0.27	3.07	0.00	2.7
Combination trucks	76.53	8.62	14.03	5.19	26.63	0.00	12.5
Total	621.72	264.40	122.80	5.46	32.09	0.50	100.0

a State Revenue Attribution is based on a methodology that yields $1,031.77 million in estimated attributable revenues. This is within 0.45 percent of actual revenues in categories defined for purposes of this study as attributable.

TABLE 17

State Revenue Attribution by Vehicle Class
Average For Fiscal Year 1988 and Fiscal Year 1989 Study Period
(in Millions of Fiscal Year 1989 Dollars) [a]

Class	Payments	Percent
Cars, motorcycles and pickups	855.27	80.3
Buses	4.68	0.5
2-axle, 6-tire trucks	44.82	4.2
3-axle or more single-unit trucks	26.59	2.5
Combination trucks	133.45	12.5
TOTAL [b]	1,064.81	100.0

a Two-year average computed from Tables 15 and 16. Fiscal year 1988 values were converted to fiscal year 1989 dollars using the VDOT construction index (fiscal year 1988 = 1.061, fiscal year 1989 = 1.0).

b State revenue attribution is based on a methodology that yields an average of $1,033.4 million in estimated attributable revenues for the two-year period. This is within 2.9 percent of actual revenues in categories defined for purposes of this study as attributable.

taxes are allocated to DMV for collection costs.) Private and for-hire motor carrier owners and operators pay a road use tax of 19.5 cents per gallon for all vehicles with more than two axles. The State Corporation Commission credits those motor carriers paying road use taxes 16.0 cents per gallon for fuel purchased within the Commonwealth. Motor fuel, special fuels, and road use taxes contributed approximately 45 percent of the total state revenues for highways in fiscal years 1988 and 1989. Fuel consumption, and therefore fuel and road use taxes as well, are functions of vehicle miles traveled and fleet fuel efficiency. For this study, fleet fuel efficiency estimates are based on data taken from the Motor Vehicle Manufacturers Association (MVMA) annual reports for 1989 and 1990. VMT data by vehicle class were collected from the Highway Performance and Monitoring System official travel figures for the study years.

In the simplest sense, estimating the fuel tax base requires dividing VMT by estimated fuel efficiency (miles per gallon) for each class to derive an estimate of gross gallons used. Several adjustments are necessary, however, to derive accurate estimates of net taxable gallons used by each vehicle class. These adjustments include accounting for fuel delivered to and used by state, local, and municipal fleets, and fuel used by school buses and transit buses. All fuel used by these vehicles is exempt from tax and is excluded from attribution. A second important adjustment involves using the SCC fuel usage records as a check on taxable gallons used and attributed to single-unit trucks and combinations. SCC records indicate that in Virginia these vehicles were taxed on 430 million gallons of fuel in fiscal year 1988 and 442 million gallons of fuel in fiscal year 1989. A third adjustment involves accounting for refunds to highway users.

Several data sources were used to determine the distribution of tax-exempt gallons to each vehicle class. These include the results of a special survey of county and municipal governments on fleet composition and usage, data from the operator of the state motor pool and the VDOT equipment manager, and data from DMV on the number of gallons delivered to government agencies.

In fiscal year 1989, 69 million gallons of tax-exempt fuel were delivered to government agencies. It is estimated that refunds were made on slightly more than 13 million gallons of fuel for highway use; of this amount, agricultural vehicles, intercity regular route buses, ready-mix concrete trucks, and taxi refunds comprise the majority. Based on the government survey results, over 50 percent of tax-exempt gallons are estimated to be used by personal use vehicles.

Employing the three adjustments just noted, and the VMT and fuel efficiency data described above, state motor fuels tax revenues were estimated to within 7.4 percent of actual revenues in fiscal year 1988. The error in fiscal year 1989 was within 2.45 percent of actual collections.

Motor Vehicle Sales and Use Tax

Approximately 20 percent of total state revenue collections (HMOF and TTF combined) come from the three percent tax imposed on the sale and rental price of motor vehicles. Total receipts from this source range from approximately $265 to $270 million for fiscal year 1988 and fiscal year 1989. The attribution of these revenues is based on the results of a special study conducted by DMV that extracted actual payments by vehicle class for the study period. In fiscal year 1989, for example, personal use vehicles contributed 92 percent of total collections, with the other four classes contributing the remaining eight percent.

Motor Vehicle Registration Fees

Passenger cars are required to pay vehicle registration fees established by Section 46.2-694 of the Code of Virginia. Motor vehicle registration fees for trucks are established by Section 46.2-697 of the Code. The Truck Trailer Survey conducted annually by DMV contains data on total fee collections by gross vehicle weight category and vehicle configuration.

In addition, the Department of Motor Vehicles conducted a special 21-month study of their accounting master file for fiscal years 1988 and 1989. They extracted registration data categorized by vehicle class and axle configuration. The resulting distributions from actual data were used to attribute the net revenue collections from the 5.1 million vehicles registered in the Commonwealth during the study period. The percentage distributions based on the special study are shown in Table 18.

TABLE 18

Vehicle Registration Fee Payment Proportions
by Vehicle Class -- Fiscal Year 1988 and Fiscal Year 1989

Vehicle Class	Percent Contribution
Cars, motorcycles and pickups	74.0
Buses	0.1
2-axle, 6-tire trucks	9.0
3-axle or more single-unit trucks	5.5
Combination trucks	11.4
Total	100.0

Source: DMV Special 21-Month Study of Accounting File

International Registration Plan (IRP)

Virginia is a member of the IRP, which governs the distribution of registration fee receipts for interstate carriers among the 39 U.S. member states. Under the IRP, registration fees are prorated for interstate carriers based on the proportion of the vehicle's total annual mileage accumulated in each state. For example, if a truck is registered in North Carolina but accumulated 60 percent of its annual mileage in Virginia, Virginia is entitled to receive 60 percent of the registration fee for that vehicle as if it were registered in Virginia. Trucks registered in most non-IRP states pay no Virginia registration fees regardless of the amount of travel on Virginia highways.

IRP revenues are categorized as "Miscellaneous Taxes and Fees" in the HMOF Statement of Revenues and Collections. According to the Commonwealth Accounting and Reporting System (CARS) Net Revenue Fund Report, Virginia received $24.37 million in registration fees under IRP in fiscal year 1988. These net revenues increased to $32.09 million in fiscal year 1989.

As was the case with vehicle registration attribution, DMV undertook a special study to extract collections by truck class registered under the IRP in Virginia. Although data on non-Virginia based carriers are not maintained by DMV in sufficient detail, data were extracted for all Virginia-based carriers by axle configuration and weight group. The special study showed that two-axle, six-tire trucks pay 7.5 percent, single-unit trucks pay 9.5 percent, and combination vehicles pay 83.0 percent of IRP fees for Virginia-based carriers. Several attempts were made to gather data on IRP carriers in other states but these were not successful; therefore, Virginia-based IRP payment proportions were used in the attribution.

FEDERAL REVENUE ATTRIBUTION RESULTS

Federal Fuels Taxes

Effective January 1, 1987, the federal gasoline tax increased from nine cents to 9.1 cents per gallon, and the diesel fuel tax increased from 15.0 to 15.1 cents per gallon. The additional one-tenth of one cent per gallon tax supports the Federal Leaking Underground Petroleum Storage Tank Trust Fund. This amount, however, is excluded from attribution analysis. In addition, the study team has determined that for the purposes of this study, the one cent per gallon of the fuel tax that is dedicated to the Federal Transit Fund will not be attributed.

There is a straightforward method of estimating federal fuels tax payments by vehicle class, since both the federal and Virginia fuels taxes are fixed cents-per-gallon levies. In particular, each class effectively pays a federal fuel tax of $.08 per gallon of gasoline and $.14 per gallon of diesel fuel used. These tax rates, combined with the estimates of net taxable gallons, exemptions, refunds, and collections by the SCC for the road use tax, render the attribution of federal fuels tax payments relatively straightforward.

Federal Excise Taxes

There are three federal excise taxes that provide revenue for the federal-aid highway program:

- a graduated truck tire tax based on three weight groups,
- a 12 percent sales tax on the retail price of tractor trucks greater than 33,000 pounds (GVW), and trailers greater than 26,000 pounds GVW, and
- a tax on vehicles registered at gross weights above 55,000 pounds.

Discussions with staff from the Federal Highway Administration resulted in a suggestion to attribute the tire excise tax on the basis of the distribution of vehicle miles traveled by each truck class weighted by the number of tires used by each typical truck in the class. Other techniques were discussed, but FHWA staff strongly argued for a heavy influence of VMT by trucks. This technique was adopted with the result that approximately 68 percent of the tire excise tax is attributed to combination trucks. This does not appear unreasonable in view of the high tax rate on heavy tires (a small truck tire weighing 48 pounds has a tax of $.65 while a large truck tire weighing 121 pounds is taxed approximately $26).

The special sales tax study conducted by DMV in conjunction with data released by R. L. Polk on sales of new vehicles in Virginia provided a straightforward means of attributing the revenues generated from a 12 percent retail sales tax on tractors, trucks greater than 33,000 pounds, and heavy trailers. In fiscal year 1989, combination vehicles accounted for almost 60 percent of these revenues, and single-unit trucks accounted for approximately 37 percent.

The third federal excise tax is collected on motor vehicles of 55,000 pounds GVW or more, at a rate of $100 plus $22 per 1,000 pounds over 55,000 pounds GVW. This tax has a maximum of $550 per vehicle registered. The FHWA reports that in fiscal year 1989 this tax on registered vehicles in Virginia totalled $17.44 million. DMV registration records and the Truck-Trailer Survey indicate that there are no single-unit vehicles registered above 55,000 pounds GVW in Virginia. For this reason, all heavy use taxes are attributed to combination vehicles.

The results of the attribution of federal revenues are shown in Tables 19, 20 and 21.

TABLE 19

Federal Revenue Attribution by Class and Source
Fiscal Year 1988
(in Millions of Dollars)

Class	Fuel	Retail Tax	Heavy Use Tax	Tires	Percent
Car/2A4T	210.59	-----	-----	-----	61.0
Buses	1.40	-----	-----	-----	0.4
2A6T	9.55	1.45	-----	2.71	4.0
SU3+	6.73	13.27	-----	0.33	5.9
Combinations	54.77	21.50	16.49	6.35	28.7
TOTAL	283.04	36.22	16.49	9.39	100.0

TABLE 20

Federal Revenue Attribution by Class and Source
Fiscal Year 1989
(in Millions of Dollars)

Class	Fuel	Retail Tax	Heavy Use Tax	Tires	Percent
Car/2A4T	245.52	-----	-----	-----	62.6
Buses	5.84	-----	-----	-----	1.5
2A6T	10.63	1.38	-----	2.65	3.8
SU3+	9.15	12.63	-----	0.28	5.6
Combinations	58.85	21.53	17.44	6.11	26.5
TOTAL	329.99	35.54	17.44	9.04	100.0

TABLE 21

Federal Revenue Attribution by Vehicle Class
Average For Fiscal Year 1988 and Fiscal Year 1989 Study Period
(in Millions of Fiscal Year 1989 Dollars)[a]

Class	Payments	Percent
Cars, motorcycles and pickups	234.47	61.8
Buses	3.66	1.0
2-axle, 6-tire trucks	14.61	3.8
3-axle or more single-unit trucks	21.82	5.8
Combination trucks	104.53	27.6
TOTAL	$379.09	100.0

[a] Two-year average computed from Tables 19 and 20 using the VDOT Construction Cost Index.

STATE AND FEDERAL REVENUE ATTRIBUTION SUMMARY

Tables 22, 23, and 24 summarize the results of the state and federal revenue attribution analysis. As shown in Table 25, the findings are comparable to those of the previous study conducted by JLARC in 1981, with some reduction in the proportions paid by single-unit trucks. Increases in fees on heavy trucks at the federal level account somewhat for the slight increase in the proportion of revenues (16.5 percent) paid by combination trucks, compared to the results in 1981 (16.0 percent).

TABLE 22

State and Federal Revenue Attribution by Class
Fiscal Year 1988
(in Millions of Dollars)

Class	State Taxes	Federal Taxes	Total	Percent
Car/2A4T	823.16	210.59	1,033.75	75.7
Buses	2.13	1.40	3.53	0.3
2A6T	43.10	13.72	56.82	4.2
SU3+	23.91	20.33	44.24	3.2
Combinations	128.10	99.09	227.19	16.6
	1,020.40	345.13	1,365.53	100.0

TABLE 23

State and Federal Revenue Attribution by Class
Fiscal Year 1989
(in Millions of Dollars)

Class	State Taxes	Federal Taxes	Total	Percent
Car/2A4T	837.17	245.52	1,082.69	75.2
Buses	7.10	5.84	12.93	0.9
2A6T	43.91	14.67	58.58	4.1
SU3+	27.81	22.07	49.88	3.5
Combinations	130.99	103.92	234.91	16.3
	1,046.98	392.02	1,438.99	100.0

TABLE 24

State and Federal Revenue Attribution by Class
Two-Year Average -- Fiscal Year 1988 and Fiscal Year 1989
(Millions of Fiscal Year 1989 Dollars) [a]

Class	State Taxes	Federal Taxes	Total	Percent
Car/2A4T	855.27	234.48	1,089.75	75.5
Buses	4.68	3.66	8.34	0.6
2A6T	44.82	14.61	59.43	4.1
SU3+	26.59	22.82	48.41	3.4
Combinations	133.45	104.53	237.98	16.5
	1,064.81	379.10	1,443.91	100.0

[a] Two-year average computed from Tables 22 and 23 using the VDOT Construction Cost Index.

NOTE: Percent column does not sum to 100 due to rounding.

TABLE 25

State and Federal Revenue Attribution by Class:
Comparison of 1990 VDOT Study and 1981 JLARC Study
(in Millions of Dollars)

Class	1981 JLARC	1990 VDOT 2-YR. AVG.[a]
Cars, pickups, panel trucks, motorcycles	74.0	75.5
2-axle, 6-tire trucks and buses[b]	6.1	4.3
3-axle or above trucks, buses[b]	3.9	3.7
Combination trucks	16.0	16.5
	100.0	100.0

[a] Two-year average derived from Table 25.

[b] For purposes of comparison, bus revenues from the VDOT study are split between the two-axle and three-axle categories with approximately one third going to two-axle buses and two thirds going to three-axle buses.

CONCLUSIONS

COSTS VERSUS REVENUES

To determine whether vehicle classes met their cost responsibility, it was necessary to compare the proportion of costs attributable to vehicle classes with the proportion of revenues paid by each. Revenues could be determined for only five vehicle classes, thus, the level of detail available for revenue payments drove the analysis. Cost responsibilities for the nine vehicle classes and five weight groups were aggregated to the same classes as available for the revenue attribution.

In Table 26, the shares of costs and revenues are presented, as well as the revenue-to-cost ratios based on these shares. The revenue-to-cost ratio represents the proportionate share of revenue received for each percent of cost. A ratio of one means revenues exactly balance costs. Ratios less than one represent underpayment of that vehicle class, and ratios greater than one indicate an overpayment.

TABLE 26

Vehicle Class Shares of Cost Responsibility
and Revenue Payments

Shares

Vehicle Class	Costs (Percent)	Revenue (Percent)	Share Ratio (R/C)
Passenger	71.1	75.5	1.06
Buses	2.0	0.6	.30
Light Trucks	5.3	4.1	.77
Single Units	4.0	3.4	.85
Combinations	17.7	16.5	.93

NOTE: Percents do not add to 100 due to rounding.

The revenue-to-cost ratio for personal vehicles was 1.06. In a $1.5 billion program level, automobile owners would pay $66 million more than they occasion and approximately that same amount would not be collected from the vehicle classes that generate the cost. This example assumes that all revenues and costs are user-based and general sales tax revenues are not included.

Comparison of the costs with the revenues indicate that only the cars and personal use trucks are paying taxes and fees proportionate to their cost responsibility. All other classes are underpaying, although to varying degrees.

Buses pay less than one third of their proportionate cost responsibility. While as a class they do not produce large costs, they are exempt from most of the user fees at both the federal and state level. Therefore, for buses, the revenues do not match the costs occasioned. For the same 1.5 billion program level example, buses would be underpaying by approximately $21 million.

Of the truck classes, light trucks significantly underpay user fees. The revenue-to-cost ratio of two-axle, six-tire vehicles was 0.77, indicating 23 percent of the proportionate costs attributable to light trucks is not collected from them. This translates into $18 million in the program example. Single units underpay approximately 15 percent of their responsibility or $10 million given the example, while tractor semitrailers and truck trailers occasion 17.7 percent of the costs and underpay by seven percent or $17.5 million.

These results parallel those reported in the 1981 Virginia Cost Responsibility Study. Table 27 presents the revenue-to-cost differences from both studies. It can be observed that the revenue-to-cost share for passenger vehicles has increased in magnitude over time while that for combination vehicles has decreased.

TABLE 27

Percent Overpayment or Under Payment by Class

	Percent	
	1981	1990
Passenger	+ 4.2	+ 6.2
2A6T & Buses	-38.0	-35.6
Single Units	-16.9	-15.0
Combinations	- 0.8	- 6.8

COSTS VERSUS REVENUES FOR OVERWEIGHT VEHICLES

The difference in revenues paid versus costs occasioned is magnified at higher weights. As weight increases so does responsibility, and vehicles operating at the extreme ends of the weight spectrum produce greater costs. Almost 82 percent of the four-axle, single units' cost responsibility was attributed to those vehicles operating over 70,000 pounds, for example.

To ascertain if the revenues received from overweight vehicles was sufficient to cover the costs occasioned by them, cost and revenue-per-mile figures were developed. The total allocated costs for single-unit trucks and tractor trailers were divided by VMT to attain an estimate of the cost per mile for trucks operating over 80,000 pounds. In addition, total revenues per mile were calculated for each truck class across all weight groups. It is important to note that vehicles operating overweight include those with permits as well as illegal operations. The following table presents the ratio of revenue to cost per mile for the two truck classes.

For both single-unit and combination vehicles, the cost exceeds the revenue. The user fees obtained from overweight vehicles fails to compensate for the costs occasioned because of the fee schedule and the large number of overweight vehicles

TABLE 28

Revenue-to-Cost Ratio
for Overweight Vehicles

Single-Unit Trucks	Combinations
0.0822	0.7126

permitted to operate free of charge. Costs increase geometrically but the permit fee structure is a flat ten cents a mile charge regardless of weight. Thus, the heaviest of vehicles generates significantly greater costs without providing an appropriate increase in revenues.

OTHER COST VERSUS REVENUE CONSIDERATIONS

The cost and revenue attribution results should be considered along with two other highway finance issues that affect all vehicle classes and highway users:

- the status of Virginia as a net donor or net recipient state in terms of federal revenues, and
- the potential benefit of the general sales tax to the vehicle classes.

Regarding the first issue, during fiscal year 1988 and fiscal year 1989 the FHWA estimates Virginia contributed a total of $737.144 million to the Federal Highway Trust Fund. During this same period, Virginia received $771.682 million in federal funds for highway purposes. Thus, over the entire study period, the Commonwealth was a net recipient state, benefiting from revenues paid into the trust fund by other states. In fiscal year 1989 alone, however, Virginia was a net donor: it received $371.128 million and generated approximately $392.016 million for the Trust Fund. If Virginia remains a net donor state in the future, however, Virginians will no longer enjoy benefits from taxes paid by highway users in the other states.

Regarding the second issue of the general sales tax, Table 29 presents a comparison of fiscal year 1989 general sales tax revenues and the associated interest earnings with nonhighway related expenditures paid from the Transportation Trust Fund. These expenditures include support to other state agencies, including ports and aviation, the state funded portion of transit, and the imputed value of the taxes from which state and local

TABLE 29

Potential Subsidy From General Sales Tax -- Fiscal Year 1989
(in Millions of Dollars)

General Sales Tax Revenue	216.70
Prorated Interest Earnings	2.08
Subtotal General Source Funds	218.78
Less Nonhighway Related Expenditures:	
Support to Other State Agencies	62.53
State Funded Portion of Transit Assistance[a]	40.91
Support to Government through Exemptions	10-15
Subtotal General Government Expenditures	113.54-118.54
Net General Source Funds	100.34-105.34

[a] The prorated transit portion of federal revenues was approximately $32.9 million of total federal tax receipts; therefore, this amount was deducted from total transit expenditures to derive the implicit "State Funded" portion.

governments are exempt. This last category is the sum of the fuels tax exemptions, refunds, registration fees, and vehicle sales and use tax exemptions that support all levels of government in the Commonwealth.

The total for non-highway related expenditures defined in this manner is approximately $114-$119 million. When subtracted from general sales taxes and prorated interest earnings for fiscal year 1989 ($218.78 million), the net remaining from the sales tax for highway purposes is approximately $100-$105 million. It is this amount (net general source funds) that may be viewed as a benefit in support of transportation for economic development purposes as recommended by COT-21.

In making comparisons between the percent of revenues and costs contributed by each vehicle class, it must be recognized that the general sales tax funds -- a substantial share of transportation revenues -- are excluded from attribution. Although allocation is not appropriate for the reasons discussed earlier, this factor qualifies the estimated relationships between the shares of revenues and costs attributed to each vehicle class. Therefore, conclusions about appropriateness of revenue mixes are incomplete without considering the general sales tax revenues and their role in transportation financing.

CONCLUSIONS ON APPROPRIATENESS OF REVENUE STRUCTURES

The relative shares of costs will remain the same as long as the program is stable and the same proportion of expenditures are allotted to maintenance, construction, administration, and safety. If the funds were to be distributed differently or if VMT were to continue to increase more for trucks than cars, the relative cost responsibility shares would change.

Comparison of the costs with revenues indicate that only cars and personal use trucks are paying taxes and fees proportionate to their cost responsibility. While cars and small trucks overpay by approximately six percent, because they represent 76 percent of the revenue, the overpayment represents a large "contribution" to the highway fund.

All other classes underpay. Buses pay little in terms of their cost responsibility. The subsidy to buses may be intended, however, in order to make urban and intercity bus travel more competitive with automobiles. The underpayment may be considered an indirect subsidy to ensure the modes continuing viability. It can also be argued that the same amount of funds would otherwise be provided to transit agencies as a direct grant.

Within truck classes, light trucks significantly underpay their cost responsibility. And while the revenue-to-cost ratio share for single units is greater than for five-axle combinations, the dollar amount is less. Probably the largest truck subsidy is for overweight operations. The estimated data suggest vehicles operating over 80,000 pounds significantly underpay according to their assessed responsibility. Many vehicles operate without additional permit fees and the charges for overweight permits paid by some vehicles appear to underrepresent the costs required to build and maintain the roads and bridges for these vehicles.

The results indicate an imbalance in the revenue mix based on a cost-occasioning methodology. However, conclusions on the need to modify the current mix of revenues from the vehicle classes depend on the extent to which the General Assembly views the sales tax as a mechanism to offset shortages in user fee receipts for particular vehicle classes.

RECOMMENDED STUDIES

Cost responsibility studies focus on the relative vehicle revenue-to-cost shares. They also address a specific funding level and program emphasis which will change over time. It is, therefore, recommended that a cost responsibility study be undertaken on a periodic basis, at least every decade, and that supplemental studies be performed to ensure state-of-the-art developments in pavement and bridge theory can be incorporated in the study design.

In that regard, if the Department of Transportation will be charged with periodic studies, it is recommended that VDOT perform an evaluation of the effect of traffic levels on pavement performance. As noted in the pavement cost allocation discussion, an attempt was made to establish a relationship between ESALs and pavement wear but the resulting models were unsatisfactory. Resurfacing costs should be allocated to vehicles based on their share of the need to repair the roadway. In order to assign resurfacing costs to classes in relation to their share of the damage, the relationships among traffic volume, vehicle weight, and pavement damage must be better understood. Pavements wear by cracking, losing skid resistance, rutting, among other reasons. Pavement research has shown that axle loadings play an important role in the development of these distresses. Different distresses affect overall pavement performance and serviceability in different ways, and using the information on pavement performance theory to assign deterioration costs to traffic should be pursued.

The estimation of pavement costs may also be improved with the development of models based on life-cycle costing. Such models as EAROMAR and IIYPAV attempt to determine costs over the entire life of the pavement, including design, construction, maintenance, and resurfacing. To date, this approach has not been used for cost responsibility but several studies at the federal level are advancing the ability of the models to be successfully applied to this issue. The constraint in its application in the future may well be the data requirements for such a modeling effort.

If the Department were mandated to perform another cost responsibility study, its electronic data bases should be reviewed to ensure accessibility of information for that specific purpose.

In addition, if there is interest in determining user fee equity for a larger number of vehicle types, or within classes, revenue information should be collected in greater detail. Enhancements are needed in the collection, format, and retrieval capabilities for revenue data but it should be recognized that additional costs would be incurred.

The SCC should revise its data collection format to include axle configuration, registered weight, fleet size, and exempt status (for certain private use and agricultural vehicles) for all vehicles it registers for the road use tax. Records should be maintained on a continuous basis and an annual report prepared and published in a format including axle configuration and registered weight in 5,000 pound to 10,000 pound weight groups that shows the net revenue generated by each group.

The Department of Transportation and the Department of Motor Vehicles should maintain permit records by axle configuration and registered weight groups in a format that shows net revenues generated by each group and publish an annual report of this information.

The Department of Motor Vehicles should revise its data collection and reporting for licenses, registration fees, sales and use taxes, other miscellaneous taxes and fees, IRP, fuel refunds, fuel and other exemptions, and the Truck-Trailer Survey to include net revenue collections in support of the Highway Maintenance and Operating and the Transportation Trust Fund. The revised format should compile these net revenue collections for each vehicle class by axle configuration and weight group as described above. The data should be either published annually or maintained in easily retrievable historical files.

The collection of this information would allow for a more detailed cost assessment of the vehicles using the roads and bridges of the Commonwealth and would be considered essential to the implementation of another cost responsibility study.

APPENDIX A

SENATE JOINT RESOLUTION 121

SENATE JOINT RESOLUTION NO. 121

Requesting the Virginia Department of Transportation to study the cost responsibility of vehicles using the highways of the Commonwealth.

Agreed to by the Senate, January 31, 1989
Agreed to by the House of Delegates, February 16, 1989

WHEREAS, the highway system of the Commonwealth is built to accommodate a variety of vehicles which have a wide range of requirements for pavement width and strength; and

WHEREAS, in cases where construction and maintenance expenditures are made due to the needs of particular vehicles, those costs should be borne by the vehicle classes that require them; and

WHEREAS, changing factors such as vehicle design, travel patterns, and economic conditions will alter the cost responsibility of vehicle classes over time; and

WHEREAS, the Joint Legislative Audit and Review Commission completed the last analysis of vehicle cost responsibility in November of 1981, and recommended that an update of the analysis be completed on a periodic basis; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the Virginia Department of Transportation review the cost responsibility of vehicle classes using the highways, roads, and streets of the Commonwealth and make recommendations to the 1991 General Assembly on the need for modifications to the current mix of revenues from the vehicle classes.

The Joint Legislative Audit and Review Commission shall review and comment on the methods and analysis to be used by the Department, and the Commission shall receive the report of the Department; and, be it

RESOLVED FURTHER, That the Clerk of the Senate prepare a copy of this resolution for presentation to the Commonwealth Transportation Commissioner and the Director of the Joint Legislative Audit and Review Commission.

APPENDIX B

USER FEES DURING THE STUDY PERIOD

APPENDIX B

USER FEES DURING THE STUDY PERIOD

	FEDERAL	STATE
Gasoline tax	9.1 cents*	17.7 cents
Diesel fuel	15.1 cents*	16.2 cents
"Road use tax"	---	19.5 cents
Registration fee	---	graduated
Vehicle sales tax	12 percent trucks > 33,000 gvw trailers > 26,000 gvw	3.0 percent
Use tax	graduated > 55,000 gvw	---
General sales tax	---	0.5 percent
Tire tax	graduated > 40 pounds	---

* On December 1, 1990 an additional five cent to became effective, two and one-half cents of which is allocated to the Federal Trust Fund.

* The one tenth of one cent per gallon tax supports the Federal Leaking Underground Petroleum Storage Tank Trust Fund.