is that the user charges do not contain any fixed or annual components, such as registration or weight fees. Efficient prices, based on short-run marginal costs, would be sufficient to raise revenues on the current system that would cover at least a share of the fixed costs of the system without levying any access charges. Unless more revenues are desired, there is no need to allocate fixed costs of highway construction to vehicle classes for purposes of calculating highway user charges. Instead, the task is to estimate more accurately the true marginal costs of highway use and to design collection instruments that approximate the correct prices at the least cost.

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*Abridgment*

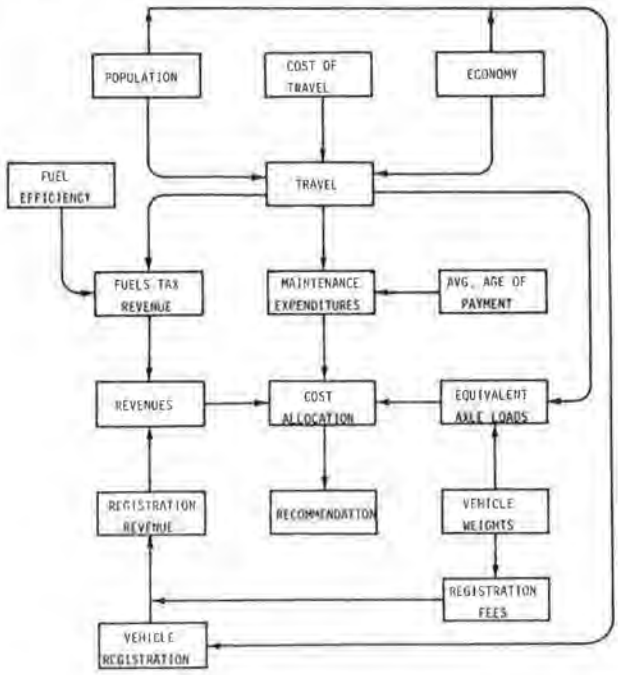
# Maintenance Cost-Allocation Study for Virginia's Interstate Highways

ANTOINE G. HOBEIKA AND THANH K. TRAN

The maintenance cost responsibilities for all classes of highway users on Virginia's Interstate highways are examined. The purpose is to compare the future fuel-tax and registration-fee revenues to the future maintenance expenses contributed by each class of vehicles. The study is composed of four major steps: (a) forecasting travel on each route by each class of vehicles, (b) forecasting general and replacement maintenance expenditures on each route, (c) forecasting of fuel-tax and registration-fee revenues contributed by each class of vehicles on each route, and (d) allocation of maintenance expenditures. The allocation of general maintenance expenditures was performed by using the vehicle miles of travel for each class. The replacement maintenance expenditures, on the other hand, were divided into two categories: weight-related (allocated based on the equivalent single axle load) and environmental-related (allocated according to travel). The results show a cross-subsidy among different classes of vehicles and also among different routes. Heavily traveled routes show high revenue-to-expenditure ratios over the study period (from 1981 to 1990). Based on the present fuel-tax rate and registration fees, the revenue-to-expenditure ratio for the Interstate system in Virginia declines significantly toward the end of the decade, which suggests the need for an increase in fuel-tax rate and registration fees.

The energy shortages in the early 1970s have forced the United States to conserve energy, especially in transportation. The conservation efforts resulted in increased automobile fuel efficiency, which in turn caused a decline in fuel-tax revenue--a major source of highway funding. The decline in revenue coupled with the constantly increasing highway construction and maintenance costs have greatly decreased the ability of state highway agencies to maintain and improve the highway system.

**Figure 1. Conceptual framework of study.**




One of the immediate solutions to this financial crisis is to raise the highway user's tax. However, to equitably charge highway users, there is a need for a study on the revenues contributed and the costs attributable to different classes of vehicles (passenger cars and light, medium, and heavy trucks). The comparison between revenues and costs helps to formulate the tax rate for each class of vehicles so that a fair cost-responsibility scheme can be developed as a basis for future highway taxation policies.

## PURPOSE

Several cost-responsibility studies have been conducted in which the total expenditures at one point are compared with the total revenues by different classes of vehicles, independent of route characteristics and of future variation in travel intensity and travel costs (1-3). Because of these shortcomings, past studies did not provide an accurate projection of revenues and highway costs and might have caused a bias in cost-responsibility assignment. In this study, the assignment of cost responsibilities was performed on a route-by-route basis for the Interstate highway system in Virginia over a 10-year period (from 1981 to 1990).

With this approach, the purpose of this study is first to formulate a taxation scheme based on their respective responsibility; second, it is to examine the future financial viability of each route. Manifestation of the former is the desired equity in taxation and of the latter is the possible innovations in highway management such as the redistribution of funds and the establishment of toll roads.

## BACKGROUND

### Interstate Highway System in Virginia

All major Interstate highways were considered in this study except those that are beltways around large metropolitan areas. These Interstate routes are heavily traveled by both passenger cars and trucks and were divided into two groups: (a) major through-state routes, which include I-81 (western Virginia) and I-95 (eastern Virginia) and (b) local or feeder routes, which include I-66, connecting I-81 and the Washington, DC, metropolitan area; I-64 in central Virginia, intersecting I-81 and I-95; and finally I-77, running through the southwestern tip of the state and intersecting I-81. The location of the routes plays a significant role in the forecast of travel, which will be discussed later.

### Classification of Vehicles

Vehicles that use Virginia highways are grouped into four classes corresponding to the way in which traffic-volume data are maintained. The four classes are as follows:

Class 1, which includes passenger cars, panel and pickup trucks, and two-axle, four-tire trucks;
Class 2, which includes two-axle, six-tire trucks (small dump and delivery trucks);
Class 3, which includes three-axle, six- to ten-tire trucks (primarily heavy dump trucks); and
Class 4, which includes three-, four-, and five-axle combination trucks.

Buses are excluded from the study because of their extremely low volume on these Interstate routes. These classes of vehicles are used to more accurately determine the fuel-tax and registration-fee revenues and also to allocate maintenance expenses based on travel intensities and weights.

## FRAMEWORK OF STUDY

The framework of the study is illustrated in Figure 1; it includes four major tasks: travel forecast, maintenance-expenditure forecast, revenue forecast, and cost-allocation analysis.

As shown in Figure 1, travel is a function of the state population, state economy, and travel cost. The influence of travel cost on trailer trucks, however, is assumed to be negligible since (a) the travel cost incurred to trailer trucks is more likely to be passed to the users of the commodities being transported and (b) the shift in transport mode and/or changes in demand due to increased travel cost may not be realized at the route level.

The forecast of travel in conjunction with the age of the pavement is then used to forecast maintenance expenditures for each route. Two other uses of the travel forecast are the estimation of fuel-tax revenues and the equivalent single axle loads (ESALs). The former is also a function of the fuel efficiency of each class of vehicles, whereas the latter is a function of vehicle weights. The second component of revenues--registration--is a function of registration fees and vehicle registration. Registration fees in Virginia are based on the vehicle gross weight for vehicles not designed or used for transportation of passengers. Vehicle registration was determined as a function of the population and the economy. From these estimated parameters, the cost-allocation analysis was performed. In the following section, a detailed description of each task is presented.

## DESCRIPTION OF TASKS

### Travel Forecast

Multiple linear regression analysis was applied to forecast the average daily vehicle miles of travel (VMT) by each class of vehicles on each route. The

data set used includes the values of a number of independent variables from 1970 to 1979. The VMT for class-1 vehicles is assumed to be a function of the average household income, the number of households in the state, and the automobile operating cost per mile. These variables were selected based on the hypothesis that the majority of vehicles in this class are automobiles and the travel characteristics are more or less in the category of personal travel. For classes 2 and 3, the independent variables are the same: total state population, total state personal income, and truck operating cost per mile. The truck operating cost per mile was used because the travel by these classes is more local (short distance) in nature and the majority of these trucks is privately owned. Finally, the variables used to forecast travel of class-4 vehicles are the state population and the total personal income since the travel of heavy trucks is assumed to be more related to the state's economy.

In the modeling process, I-81 and I-95 were considered as the major routes in the state because they are more frequently used for all trips. It is therefore hypothesized that the travel on I-81 and I-95 would have an effect on the travel on other routes. Thus, VMT on I-81 and I-95 was used as the independent variable in the equations for other routes. The results have shown that truck travel (classes 2, 3, and 4) on I-81 and I-95 indeed affects truck travel on other routes. The same phenomenon did not occur for class-1 vehicles because the travel of this class is too highly correlated to household income and number of households in the state.

The forecast of the state total personal income was performed by using an annual growth rate of 10.5 percent starting in 1980 (4). The projected values for the state population were adopted from a study done by the Virginia Department of Planning and Budget (5).

## Forecast of Maintenance Expenditures

The maintenance expenditures are divided into two classes--general maintenance and maintenance replacement--according to the classification of the available data. General maintenance includes those activities that are performed every year or those that are more related to weather and environmental conditions. Maintenance replacement, on the other hand, includes the major maintenance activities that are related to travel intensity and age of the pavement.

According to historical data (6), the price index of highway maintenance increases at approximately the same rate as that of the consumer price index of overall goods (CPIOG). It is therefore hypothesized that future highway general-maintenance expenditures depend on the value of CPIOG. The forecast of general-maintenance expenditures is performed on a per-mile basis for ease of computation. Percentage of the replacement expenditures is in the pavement-related work. It is therefore hypothesized that the maintenance-replacement expenditures are functions of the total truck travel (i.e., classes 2, 3, and 4) and the age of the pavement.

In formulating the equations for maintenance-replacement expenditures, several forms of the regression model (including linear and nonlinear) were attempted and the best-fit models were selected. This trial-and-error process was used because the available data did not show a consistent pattern of expenditures among the routes.

## Forecast of Revenues

The two sources of revenue used in the study are fuel-tax revenues and registration-fee revenues. Fuel-tax revenues are computed based on the forecast VMT, the average fuel efficiency of each class of vehicles, and the state fuel tax per gallon of fuel. The projected fuel efficiency for class-1 vehicles ranged from 15.5 miles/gal in 1980 to 25.6 miles/gal in 1990. The average fuel efficiency for all trucks was assumed to increase 1.4 percent per year (7). This average figure was adjusted for classes 2, 3, and 4 vehicles by using the estimated percentages from past data (7).

The registration-fee revenues for each class of vehicles were estimated as the product of the number of registered vehicles and the fees per vehicle, which are based on their size and weight.

## Expenditure Allocation

Many different techniques have been used to allocate highway maintenance expenditures to vehicle classes (1,8,9). A common problem that exists in these techniques is the estimation of the proportion of maintenance expenditures that is related to environmental damage and the proportion that is related to traffic. The Joint Legislative Audit and Review Commission of the Virginia General Assembly (1) used a split of 77 percent and 23 percent as weight-related and environmentally related, respectively. The Federal Highway Administration (9), on the other hand, used a split of 70 percent and 30 percent as traffic-related and non-traffic-related, respectively. For this paper, 70 percent of the replacement-maintenance expenditures were assumed to be traffic-related and allocated according to the relative weight of each vehicle class by using ESALs. The remaining 30 percent of the replacement expenditures--which are assumed to be common to all vehicles--were allocated according to VMT of each vehicle class on the route.

The general-maintenance expenditures were treated as common to all vehicle classes and allocated according to VMT. This is because a large fraction of the activities are related to the environment and weather instead of to vehicle weight. Thus the cost responsibility of each vehicle class was estimated based on the use of the highways.

## Revenue Attribution

The two major sources of revenues considered, as mentioned previously, were fuel-tax revenues and registration-fee revenues. Since the VMT by each class of vehicles on each route was determined, the amount of fuel consumed is obtained by dividing the VMT by the corresponding average miles per gallon. The fuel-tax revenue attributed by each class is simply the amount of fuel consumed multiplied by the fuel-tax rate. The tax rate was held constant during the analysis period for the purpose of assessing the adequacy of future fuel-tax revenues.

The attribution of registration-fee revenues by each class of vehicles on each route was estimated as the product of the registration-fee revenues per VMT for that particular class and the VMT of that class on the route being considered.

Based on the developed equations and procedures, revenues and maintenance expenditures for each route were estimated for the period from 1981 to 1990. The following section will present the results of the study.

# RESULTS OF STUDY

## Travel

Travel increases by about 67 percent in 10 years on

most of the Interstate highways in Virginia by all classes of vehicles (from 20.2 million VMT/day in 1981 to 33.6 million VMT/day in 1990). The largest shares are carried by class-1 and class-4 vehicles. I-64, I-81, and I-95 remain the most heavily traveled routes, followed by I-495, I-66, I-77, and I-85. The travel of heavy trucks (class 4) in Virginia is primarily conducted on I-81, I-95, and I-64 in that descending order. Those routes constitute approximately 87 percent of the total travel by class-4 vehicles on the Interstate highways in Virginia. Class-1 vehicles dominate the travel on all the Interstate highways; percentages range from 49 to 91 percent of all the travel on the route. The continued growth in population and in total personal income in Virginia in addition to the decrease in the number of persons per household are the main forces behind the sustained growth in travel.

## Expenditures

The projected maintenance expenditures for the system (excluding urban beltways) increase at an annual rate of 10 percent. Class-1 vehicles, according to the model allocation procedure discussed earlier, produce the most costs; percentages range from 57 percent in 1981 to 62 percent in 1990; class-4 vehicles follow with percentages ranging from 36 to 32 percent in 1981 and 1990, respectively. Class-3 and class-2 vehicles contribute only a small share, approximately 3 and 4 percent of the total maintenance expenditures, respectively. However, this picture is not consistent over all the routes of the system. Trailer trucks (class 4) produce more total maintenance costs than class-1 vehicles on I-81, I-85, and I-495 according to the cumulative 10-year expenditures shown in Table 1. This class of vehicles comes close to producing the same costs as class 1 on I-77. In spite of this variation in cost distribution among classes, I-64, I-81, and I-95 generate most of the costs (79 percent) of the system (see Table 1).

## Revenues

Consistent with expenditures, class-1 and class-4 vehicles are the predominant generators of revenue and provide the highest fuel-tax and registration revenue, respectively. Registration revenue makes up approximately 18 percent of the total revenue, which is structured on the gross weight of the vehicle in Virginia. Besides, the annual increase in revenue, whether fuel-tax or registration, is growing at about 3 percent under the existing tax structure, compared with 10 percent annual growth in expenses.

Similar to expenditures, trailer trucks contribute more revenue than class-1 vehicles on I-81, I-85, I-77, and I-95, as shown in Table 2. With respect to total revenue, I-81, I-64, and I-95 provide the largest amounts of revenue in that descending order (see Table 2).

## Allocation Analysis

In general, the results show that the total revenue is greater than the maintenance expenses on all the routes for the study period. On the average, the ratio of revenue to expenditures varied from 1.54 to 4.11 on the different routes of the Interstate system in 1981 and will drop from 1.17 to 2.84 in 1990. Also, the revenue-to-expenditure ratio for all classes of vehicles drops from 3.07 in 1981 to 1.74 in 1990 as shown in Table 3. Classes 4, 2, 3, and 1, in that order, provide the highest percentage of revenue to expenditures. The reason for this outcome is that class-4 vehicles have the lowest number of miles per gallon of fuel and class-1 vehicles have the highest. And from the point of view of expenditure, class-1 vehicles have the most VMT on the Interstate system and therefore take a much larger share of general-maintenance expenditures, which is the major component of maintenance expenditure.

The results also show that class-1 vehicles on I-77 and I-85 and class-3 vehicles on I-495 produce revenues that are only 93, 62, and 81 percent of their contributed maintenance costs, respectively (see Table 3). There are two possible reasons for this. First, the VMT by class-1 vehicles on the first two routes and class 3 on I-495 are low compared with that for the other routes, thus causing a small contribution in gasoline-tax revenues. Second, because of the geographical location of these routes, a part of class-1 vehicles is likely

**Table 1. Total 10-year expenditures by class and route.**

| | Millions of Dollars | | | | |
|---|---|---|---|---|---|
| Route | Class 1 | Class 2 | Class 3 | Class 4 | All Classes |
| I-64 | 115.30 | 4.68 | 2.55 | 28.94 | 151.48 |
| I-66 | 23.67 | 1.01 | 1.18 | 3.31 | 29.17 |
| I-77 | 14.31 | 0.84 | 0.24 | 6.79 | 22.18 |
| I-81 | 56.76 | 3.88 | 1.63 | 53.74 | 116.01 |
| I-85 | 12.50 | 1.22 | 0.21 | 7.88 | 21.82 |
| I-95 | 46.21 | 2.69 | 2.17 | 25.76 | 76.84 |
| I-495 | 5.40 | 1.41 | 2.05 | 7.34 | 16.20 |

**Table 2. Total 10-year revenues by class and route.**

| | Millions of Dollars | | | | |
|---|---|---|---|---|---|
| Route | Class 1 | Class 2 | Class 3 | Class 4 | All Classes |
| I-64 | 171.45 | 11.04 | 3.93 | 53.32 | 239.73 |
| I-66 | 35.98 | 2.69 | 2.24 | 7.75 | 48.66 |
| I-77 | 13.27 | 1.92 | 0.61 | 20.92 | 36.73 |
| I-81 | 95.41 | 13.82 | 5.29 | 213.68 | 328.20 |
| I-85 | 7.72 | 1.86 | 0.45 | 21.04 | 31.06 |
| I-95 | 122.81 | 12.05 | 6.49 | 95.53 | 237.88 |
| I-495 | 38.66 | 3.13 | 1.67 | 7.48 | 50.93 |

**Table 3. Ratios of revenues to expenditures.**

| Route | Year | Class 1 | Class 2 | Class 3 | Class 4 | All Classes |
|---|---|---|---|---|---|---|
| By Class and Year | | | | | | |
| | 1981 | 2.57 | 3.73 | 2.54 | 3.97 | 3.07 |
| | 1982 | 2.46 | 3.63 | 2.44 | 3.81 | 2.94 |
| | 1983 | 2.24 | 3.42 | 2.32 | 3.60 | 2.72 |
| | 1984 | 2.03 | 3.23 | 2.21 | 3.42 | 2.53 |
| | 1985 | 1.91 | 3.07 | 2.11 | 3.25 | 2.38 |
| | 1986 | 1.73 | 2.88 | 2.01 | 3.07 | 2.19 |
| | 1987 | 1.60 | 2.76 | 1.94 | 2.95 | 2.06 |
| | 1988 | 1.50 | 2.67 | 1.88 | 2.85 | 1.96 |
| | 1989 | 1.41 | 2.58 | 1.82 | 2.75 | 1.86 |
| | 1990 | 1.31 | 2.46 | 1.76 | 2.63 | 1.74 |
| By Class and Route (sum of 10 years) | | | | | | |
| I-64 | | 1.49 | 2.36 | 1.54 | 1.84 | 1.58 |
| I-66 | | 1.52 | 2.65 | 1.90 | 2.35 | 1.67 |
| I-77 | | 0.93 | 2.29 | 2.54 | 3.08 | 1.66 |
| I-81 | | 1.68 | 3.56 | 3.24 | 3.98 | 2.83 |
| I-85 | | 0.62 | 1.52 | 2.14 | 2.67 | 1.42 |
| I-95 | | 2.66 | 4.47 | 3.00 | 3.75 | 3.10 |
| I-495 | | 7.16 | 2.22 | 0.81 | 1.02 | 3.14 |

to be out-of-state vehicles, whose registration-fee revenue could not be accounted for.

## CONCLUSION

The study results showed that the forecast revenues collected from each class of vehicles are greater than the expected maintenance expenditures on the Virginia Interstate highway system. They also indicated that there is a cross-subsidy among the routes in the state (i.e., heavily traveled routes generate more revenue than lightly traveled routes).

In general, heavy trucks (class 4) using the Interstate highway system in Virginia contribute more revenue than other classes of vehicles. And among all classes, the revenue-to-expenditure ratios are significantly different, which suggests a cross-subsidy even between the classes of vehicles.

With the present tax structure (fuel-tax rate and registration fees), the revenues collected from the use of the state highways in Virginia are likely insufficient to pay for the maintenance expenses, much less for the construction of new highways in the next 10 years. An increase in highway user charges seems necessary in the near future to cope with the increasing maintenance cost. Manifestation of this need is the fact that the Interstate highways have had the highest revenue-to-maintenance-expenditure ratio and this ratio seems to decline rapidly in the next 10 years.

## ACKNOWLEDGMENT

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# Transit Financing and the Cities: The Record and the Views of the Nation's Mayors

LINDA GORTMAKER

**Because of the concerns expressed by the nation's mayors and other elected officials about the financial conditions of their cities' transit systems, the U.S. Conference of Mayors, in cooperation with the Urban Mass Transportation Administration, conducted a survey in the fall of 1980 on the current local transit-financing situation across the nation. Although many studies have been conducted about individual systems or transit financing in general, none have provided a systematic, comprehensive view of the fiscal problems of the nation's major general-purpose transit systems. Although city governments have delegated the day-to-day operations of most urban transit systems to transit authorities, many transit agencies lack independent financial powers. The public turns to local elected officials to develop ways to raise funds for capital and operations. This study investigated these areas from the mayors' perspective: current support levels for transit; earmarked transit taxes and other financial resources; administrative and intergovernmental relationships; problems with federal, state, and local funding programs; fare policy and pricing; potential new funding options for cities and elected officials' reactions; voter acceptability of funding options; impact of Section 504 regulations; and recommendations from the cities themselves on ways to solve their transit-financing dilemmas. In this survey, 132 cities participated of a possible 139 major cities from urbanized areas that had a population of more than 200 000 plus two dozen smaller cities. Both telephone and mail-back interview techniques were used.**

Mayors have long recognized that public transportation is essential to their communities' vitality and economy. As financial resources at all levels grow tighter, mayors face greater challenges in financing the capital and operating costs of their transit systems. This is made even more difficult by the soaring price of gasoline and by other factors, which in many cities have pushed riderships to their highest levels. In the context of these challenges, the U.S. Conference of Mayors, in cooperation with the Urban Mass Transportation Administration of the U.S. Department of Transportation, undertook a comprehensive survey of 139 cities to document the transit-financing performance and outlook for the 1980s of the nation's cities.

The Reagan Administration's new public transportation policy emphasizes the use of federal funds for capital expenditures for transit systems but seeks a solitary local and state role in financing operating expenses after FY 1984.

The federal-state-local partnership has charac-