Abridgment

Comparison of Standard Incremental and Relative-Use Methods of Highway Cost Allocation

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As highway costs increase more rapidly than user revenues, it is clear that most states must increase user taxes to prevent further deterioration of their roadway systems. As user tax rates increase, state highway and elected officials should become more concerned with the equity of their tax structure. Recently many engineers and economists have questioned the standard incremental method of highway cost allocation, used by most states for several decades to determine the cost responsibilities of different vehicle groups. This study developed a relative-use method, partly based on the methodology developed by the Federal Highway Administration for the national cost-allocation study completed in 1982. The method presented in this study uses the original equations from the American Association of State Highway Officials road test to develop the relative use or damage associated with a single repetition of a given axle loading and then aggregates the use factors to the vehicle classes on the highway system. The new methodology as well as the standard incremental method were applied to Maryland highways, roads, and streets. Although both methods are cost occasioning in their conceptual framework, the relative-use method assigns more than twice the cost responsibility to heavy vehicles and subsequently reduces the responsibility of lighter vehicles when compared with the standard incremental method. The attempt was not to support either method nor to advocate a cost-occasioning method over marginal cost pricing; rather the paper develops a supportable method and presents the type of results obtained by its application to a typical state highway program.

By most estimates, the cost during the next 10 years to rehabilitate the nation's roadway systems will be greater than $0.5 trillion. These costs, borne solely by the public sector, will necessitate significant increases in highway user taxes and fees, since existing tax rates, if unchanged, will generate about one-third of the needed revenue. Such increases should necessarily increase public decisionmakers' concern with the equity of the proposed tax structure.

Highway cost-allocation studies are used to compare the share of user taxes paid by various classes of vehicles against the costs of highway construction and maintenance that may be attributable to each group. The results of a cost-allocation study can provide a basis to adjust total highway user revenues equitably by increasing (or decreasing) user taxes on specific vehicle groups that may be paying less (or more) than their equitable share.

This report describes the comparison of two distinct cost-allocation methodologies as they were applied to the state of Maryland; one is the standard incremental method (SIM), used extensively in many state allocation studies for more than 30 years, and the second is the relative-use method (RUM), developed for this study (1). The latter method uses partly, as a basis, the consumptive-model framework developed by the Federal Highway Administration (FHWA) for the national cost-allocation study completed in 1982 (2). Some significant changes in the FHWA method were made and considerable adaptation was necessary to apply the method to the Maryland state systems.

OBJECTIVE

The objective of this paper is simply to present and compare the results of the application of these two methods. We do not choose, at this time, to commit ourselves to which, if either, of the two methods is more correct. Nor do we wish to imply that any cost-occasioning methodology is in general necessarily the best way of pricing highway use. In fact, it can be argued soundly that society's interests can be achieved better by the implementation of some efficiency pricing mechanism, that is, some type of marginal cost pricing.

Nonetheless, it is clear that most states, with few if any exceptions, will continue to use cost-occasioning methods, and it is also clear that dozens of states will face a situation similar to the one Maryland faced last year. Thus, in the same way that the federal study in the early 1960s laid the framework for the incremental method, which was subsequently adopted by many states, the 1982 federal study will also be considered by many state highway agencies as an alternative allocation procedure.

INPUT DATA

Highways, Roads, and Streets

Before the two methods and the subsequent results of their application are described, it is necessary to present those costs that are involved. To arrive at a representative annual cost figure, the Maryland State Highway Administration (MSHA) decided to use the average of the actual expenditures for FY1979 through 1981 and the approved program costs for FY1982 through 1984.

Because of the different vehicle mix and roadway design specifications for different subclasses of the highway system, 10 different classes were analyzed: Interstate rural and urban; primary rural and urban; secondary rural and urban; county; and municipal freeway, arterial or collector, and local. In turn, the expenditures for each class were further subdivided into those costs from each of the two sources of funds--federal and state. An aggregated summary of these costs by major highway classification is presented below:

	Avg Annual Cost ($000 000s)		
System	State User	Federal Aid	Total
State highway	1.518 74	1.068 13	2.586 87
County road	0.654 82	0.021 24	0.676 06
Municipal street	0.741 08	1.853 98	2.595 06
Total	2.914 64	2.943 35	5.857 99

The costs of each roadway system were again further subdivided into seven major work items: right-of-way, grading and drainage, base and surface, shoulders, maintenance, administration, and other.

Vehicle Classification

In addition to the cost data, the second major input is vehicle miles of travel (VMT) for the various types of vehicles in the vehicle fleet. VMT data for 69 separate type and weight groups were assembled for each of the 10 roadway classes. In addition, loadometer data were collected to provide the distribution of axle loads for all vehicle groups. For the final reporting of cost responsibilities, the 69 type and weight groups were compressed into 29 groups.

Table 1. Sample PCE factors.

	Highway System Class					
	Interstate		Secondary		Municipal	
Vehicle Type	Rural	Urban	Rural	Urban	Arterial or Collector	Local
Automobile	1.00	1.00	1.00	1.00	1.00	1.00
Bus	1.30	1.54	1.60	1.30	1.30	1.40
Single-unit truck						
2A, 4T	1.09	1.11	1.14	1.20	1.20	1.20
2A, 6T	1.15	1.28	1.20	1.14	1.14	1.30
3A	1.30	1.32	1.50	1.20	1.20	1.48
Combination truck						
2S-1	1.30	1.37	1.48	1.54	1.54	1.48
2S-2	1.45	1.56	1.72	1.81	1.81	1.72
3S-2	1.70	1.87	2.12	2.26	2.26	2.12

ALLOCATION METHODOLOGIES

SIM and RUM are described in detail in the final report (1). Only the major differences between the two methodologies will be discussed in this paper.

Both methods are based on a cost-occasioning framework. That is, each vehicle group is considered responsible for the costs associated with those facilities or portions of facilities that are necessary to accommodate that particular vehicle group. Those facilities, or portion thereof, that are not attributable to any specific vehicle group and are indeed used by all vehicles are considered as the base facilities. These costs, sometimes mistakenly referred to as "common" costs, are shared by all vehicle groups. MSHA determined that the base facility was the facility necessary to accommodate a vehicle with a maximum axle load of 3000 lb. The remaining costs are attributed to vehicles with characteristics that require facilities that are thicker, wider, higher, and the like than the base facility.

SIM Allocators

For base and surface costs, SIM uses the proportion of total axle miles, with tandem axles considered as one axle, as the intraincremental allocator for each additional increment of thickness (10 thickness increments) and the base-facility thickness. This allocator--axle miles--was also used as the allocator for all costs associated with the maintenance of the base, surface, and shoulders. For all other costs, unweighted VMT was used as the allocator.

RUM Allocators

RUM uses two allocators that differ substantially from those used in SIM. For all directly non-weight-related costs, the RUM intraincremental allocator is passenger-car equivalent weighted VMT (PCE-VMT). The concept of PCEs is based on the relative reduction of level of service of a roadway, first because it is larger and requires more space than an automobile and second because, due to its high ratio of weight to horsepower, it accelerates more slowly, slows on grades, and the like. These PCE factors are a function of the vehicle traffic and roadway characteristics and reflect the results of recent extensive FHWA-contracted research. Table 1 presents a sample of the PCE factors for major visual classifications of vehicle types.

The assignment of cost responsibility occasioned by weight differs radically from SIM. RUM allocates weight-related costs on the basis of relative use or damage sustained through the cumulative repetitions of axle loadings attributable to the various vehicle type and weight groups. The relationship between this relative-use factor and axle loads is based on the pavement design equations developed from the road test of the American Association of State Highway Officials (AASHO). From the MSHA-supplied design criteria, the thickness and layer coefficients are used to compute the structural number. This in turn is used along with the axle load and serviceability index to compute the number of repetitions of that specific axle load to produce failure. The inverse number of repetitions can be defined as the use or consumption caused by a single repetition of that axle load. From loadometer data, the distribution of axle loads for all 69 vehicle type and weight groups is known. Since the use or consumption due to any particular axle load is known, there is no need to compute equivalent single axle loads (ESALs). The use assigned to each vehicle group is the aggregation of the damage of each repetition of the actual over-the-road axle loads. To demonstrate the effect of the relative-use factor, consider the example of rural Interstate highways in Maryland. The annual travel by automobiles is 1164.8 million vehicle miles and that by 78 000+-lb combination trucks is 102 million miles out of a total 1672.1 million miles traveled by all vehicles. However, because the relative use attributed to the heavy axle loads of the truck is so much greater than that attributed to the axle loads of the automobile, it results in a much greater assignment of costs to the 78 000+-lb truck:

Vehicle Type	VMT (%)	Responsibility (%)
Automobile	69.7	0.3
Combination truck (78 000+-lb)	6.1	41.8

In other words, of the weight-occasioned costs of rural Interstate highways, automobiles are responsible for about one-half of 1 percent, whereas the single class of trucks, the 78 000+-lb combination truck, is responsible for almost 42 percent.

ALLOCATION BY WORK ITEM

A detailed description of the breakdown between base facility and occasioned costs is presented in the final FHWA report (1). In general, except for the different allocators, the two methods follow standard cost-allocation procedures. A great difference was in the allocation of costs associated with reconstructed pavements and pavements that had major repairs. There is considerable controversy about the damage done to pavements as a result of the environment. Different pavement experts can effectively argue that the environment is responsible for zero to 50 percent of pavement damage. The study team decided, based on input from the FHWA, that 25 percent of pavement damage was due to environmental factors and that the remaining 75 percent was weight related. Accordingly, in RUM 25 percent of the costs of reconstructed pavements and pavements that had major repairs was assigned to the base facility and allocated (as were all base-facility costs) to all vehicles in proportion to their share of the total PCE-VMT, and all remaining costs were considered weight related and allocated to all vehicles according to the relative-use factor. In SIM these costs were allocated based on 11 increments of thickness in the same manner as new pavements.

A second difference was in the allocation of maintenance costs. In SIM, all maintenance costs were considered part of the base facility and were allocated on the basis of VMT, except for those costs associated with the maintenance of the base,

Table 2. Average annual roadway costs.

Work Item	Cost ($000 000s)	
	Incremental	Relative Use
Base and surface		
Base	0.192 98	0.095 87
Occasioned	0.095 72	0.192 83
Subtotal	0.288 70	0.288 70
Grade and drainage		
Base	0.191 17	0.191 03
Occasioned	0.017 02	0.017 16
Subtotal	0.208 19	0.208 19
Shoulder		
Base	0.027 30	0.027 26
Occasioned	0.022 19	0.022 23
Subtotal	0.049 49	0.049 49
Other		
Base	0.750 40	0.750 40
Occasioned	0.000 27	0.000 27
Subtotal	0.750 67	0.750 67
Special (occasioned)	0.014 35	0.014 35
Maintenance		
Base	0.906 80	0.968 72
Occasioned	0.317 96	0.256 04
Subtotal	1.224 76	1.224 76
Structures		
Base	0.227 76	0.222 82
Occasioned	0.150 71	0.155 65
Subtotal	0.378 47	0.378 47
Total	2.914 63	2.914 63

surface, and shoulders, which were allocated on the basis of axle miles.

In RUM, however, maintenance costs were divided into two groups--those that correct damage that is judged to be weight or size related and those that are judged to be a part of the base facility. The judgment as to which group each cost belonged was mainly subjective but relied on the accumulated expertise of MSHA maintenance engineers. Examples of those types of maintenance items that were judged to be weight related were continuous patching with bituminous concrete, deep patching, major repairs to bridge decks, and the like. Such items as joint filling, spot patching, and curb and gutter repair were judged to be not weight related. Since it was assumed that some of the weight-related repair costs were due to environmental causes, 25 percent of this group of costs was allocated on the basis of PCE-VMT and the remaining 75 percent by the relative-use factors. Those costs that were assumed not weight related were allocated in the same manner as other base-facility costs.

A stratification of the costs for all roadway systems by (a) work item, (b) type of cost (base facility or occasioned), and (c) allocation method is given in Table 2. Except for base and surface costs where RUM assumes that a large percentage of the costs for reconstructed pavements are occasioned, there is little difference between the two allocation methods. The greatest impact on the resulting responsibilities is clearly due to the differences in the allocators.

RESULTS

Average annual program costs for each highway system were allocated to 69 different vehicle type and weight groups. These groups were compressed into 29 groups. The study team investigated two revenue bases: (a) state-generated revenues only and (b) federal and state revenues combined. In turn, two sets of system costs were analyzed for each revenue base: (a) state highway system only and (b) entire roadway system (state, county, and municipal). The study team decided to analyze these four separate scenarios for several reasons. Although the state cannot affect changes in the federal user tax structure, these taxes are indeed paid by Maryland citizens and businesses, and consequently both revenue bases should be analyzed. Likewise, although the state cannot directly affect the type of expenditures made by counties and municipalities, nonetheless user tax revenues are passed through the state to the subordinate jurisdictions and therefore expenditures from user-generated revenues made on the entire system, as well as on the state system, should be analyzed and presented to state officials.

Table 3. Comparison of cost responsibilities.

Vehicle Type	Responsibility of All Systems (%)		Responsibility of State System (%)		Current User-Tax Responsibility (%)
	SIM	RUM	SIM	RUM	
Automobile	71.26	60.22	67.19	55.99	67.39
Pickup, van	12.16	10.82	13.26	11.78	13.49
Bus	1.06	2.14	0.81	1.17	0.89
Single-unit truck (lb)					
10 000	1.42	1.46	1.56	1.64	1.47
14 000	0.15	0.15	0.17	0.17	0.16
18 000	1.36	1.51	1.50	1.64	1.52
22 000	0.45	0.56	0.50	0.59	0.56
26 000	0.82	1.12	0.92	1.17	1.01
30 000	0.34	0.56	0.38	0.55	0.38
34 000	0.96	1.70	1.10	1.84	1.31
38 000	0.42	0.94	0.47	0.92	0.56
42 000	0.05	0.08	0.06	0.10	0.08
46 000	0.11	0.18	0.13	0.22	0.17
50 000	0.04	0.06	0.04	0.07	0.06
54 000	0.02	0.05	0.03	0.05	0.03
56 000	0.39	0.71	0.47	0.81	0.58
Subtotal	6.53	9.08	7.33	9.77	7.89
Dump truck (lb)					
40 000	0.14	0.45	0.15	0.39	0.23
65 000	1.13	3.35	1.33	3.43	1.86
Total, single-unit truck	7.80	12.88	8.81	13.59	9.98
Truck tractor (lb)					
40 000	0.15	0.21	0.19	0.23	0.16
44 000	-	0.01	0.01	0.01	-
48 000	0.02	0.04	0.02	0.04	0.01
52 000	0.33	0.60	0.40	0.68	0.33
56 000	0.13	0.26	0.15	0.27	0.12
60 000	0.09	0.16	0.12	0.20	0.11
64 000	0.05	0.09	0.06	0.11	0.06
68 000	1.63	3.16	1.94	3.34	1.71
72 000	0.04	0.08	0.05	0.09	0.04
76 000	2.04	3.98	2.44	4.35	2.22
79 000	3.24	5.35	4.55	8.15	3.49
Total, truck tractor	7.72	13.94	9.93	17.47	8.25

The results of all the scenarios for all vehicles cannot be presented here; however, Table 3 presents, as an example, the results of the analysis for the allocation of state revenues for all roadways and for state-owned systems. It is evident that the differences between the two methods are quite large. RUM, when compared with SIM, clearly results in significantly larger cost responsibilities for heavier vehicles and smaller responsibilities for lighter vehicles. For vehicles with high axle loadings, combination trucks, and dump trucks, RUM results in a two to three times greater responsibility than SIM. These results vary somewhat for each scenario due to the differences between vehicle mix and construction and maintenance program for each system and due to the different funding formulas for different programs. Nonetheless, the trend is clear: as axle loads increase, the cost responsibilities increase more rapidly. These differences in responsibilities, although large, are not unexpected, since RUM directly assigns costs as a function of the relative use or damage occasioned by axle loading as determined by the AASHO road-test equations.

Of course, in a state highway program, only a small percentage of the total program dollars is spent on new construction and major rehabilitation (about 10 percent in Maryland), and in fact only 22 percent of all roadway costs were judged size and weight related. Consequently, automobiles, pickup trucks, and vans are clearly assigned a large majority of total program costs.

Table 3 also presents a comparison of the two sets of responsibilities with the percentage of the current total Maryland user-tax payments. Thus, in Maryland, the allocations determined by the application of each method result in distinctly different policy implications. When the SIM results are used, automobiles pay slightly less than their fair share, whereas the RUM results indicate that automobiles pay much more than their fair share. For heavy combination trucks, the RUM results indicate that a doubling of the annual user taxes is appropriate in terms of equity.

CONCLUSIONS

It is not the purpose of this paper to argue which cost-allocation methodology is best; rather it is to discuss the basis of a new method, RUM, and present a comparison of the assigned cost responsibilities. Both methods have strong proponents among engineers and economists, and until a consensus determines which method is best, this subject will remain controversial.

Both of these methods, however, in their most basic framework use a cost-occasioning theory. That is, each vehicle group is assigned a share of the total roadway cost based on the costs caused or occasioned by the group. Neither method attempts to address the efficiency issue. It is clear that efficient pricing of the roadway system would rely on an application of some type of marginal cost pricing. However, until an implementable (politically and technically) marginal cost-pricing plan is developed, states will no doubt rely on a cost-occasioning methodology.

REFERENCES

1. Federal Highway Cost-Allocation Study. FHWA, Final Rept., Vols. 1 and 2, May 1982.
2. Maryland Cost-Allocation Study. Department of Civil Engineering, Univ. of Maryland, College Park, Jan. 1983.

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Use of Multiple-Time-Series Framework to Identify and Estimate Quarterly Model of Gasoline Demand

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A portion of the work performed in developing a revenue-forecasting model used by the Wisconsin Department of Transportation is reported. A single-equation econometric model of gasoline demand is developed and tested by nesting the model within a more general multiple-time-series framework. Use of an appropriate disturbance structure for the model has significant effects on the model's fit and estimated elasticities. The results also indicate that direct and indirect models of gasoline demand are both consistent with the data. The forecasting performance of alternative specifications of the gasoline demand model is evaluated, and it is shown that the multiple-time-series specifications are clearly superior. These results support the use of a multiple-time-series framework and detailed diagnostic checks when time-series data are used to estimate models of gasoline demand and other economic processes.

Forecasting the demand for gasoline is of obvious importance to sound transportation planning at the state level. Over the last 10 years, considerable attention has been directed to this issue. The bulk of the research has concentrated on the identification and estimation of econometric models of demand. Typically, these models have been estimated by using either time-series or cross-sectional time-series data. Early models were often based on annual observation periods, but models based on quarterly or monthly observations are becoming increasingly common. Recent surveys of the literature on gasoline demand modeling are contained in papers by Beaton and others (1) and by Hartman, Hopkins, and Cato (2).

For the most part, the gasoline demand models in existence today have been developed by using a traditional econometric modeling approach. There has been no systematic attempt to integrate econometric and time-series-analysis techniques. In recent years, a number of authors [Zellner and Palm (3), Wallis (4), and Howrey (5)] have shown that structural econometric models are special cases of more general multiple-time-series processes. Howrey (5, p. 278) indicates the importance of this result by stating that "if the assumptions of a structural econometric model place restrictions on a more general time series model, the time series model will provide a vehicle to test the validity of those restrictions, and hence the adequacy of the econometric model." By testing restrictions in this way, it is possible to develop models that use more of the information contained in the sample data. This approach should lead to models with improved specifications and forecasting properties.

At the Wisconsin Department of Transportation (WisDOT), a multiple-time-series framework has been adapted for use in modeling and forecasting quarterly gasoline demand (highway). The results of the modeling effort highlight the advantages that a multiple-time-series framework has in terms of model identification and forecasting. The purpose of this paper is to briefly discuss the approach used and the results obtained in developing this model. The approach is easily implemented (6) and should be of value to any researcher using time-series data to model and forecast economic processes. In Wisconsin, a multiple-time-series framework has also been used to develop quarterly models for automobile and truck sales, demand for special fuel (highway), and highway construction cost inflation. A detailed