Update Analysis of Highway Cost Allocation

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Many states have recently performed cost allocation studies to provide a logical basis for formulating equitable tax structures and registration fee schedules. Many states have also recognized the dynamic nature of the problem, and the need to conduct an update analysis periodically. A full-scale update analysis is often costly and time consuming and little effort has been made to address this problem. Using the 1988 Indiana update analysis of highway cost allocation as an illustration, the key elements in an update analysis are identified here and a recommendation is made that the establishment of a permanent cost allocation data base would enable an update analysis to be conducted periodically in an efficient manner within a time frame acceptable to most highway agencies. The important steps in the Indiana update study are described and examined in detail. Study results and findings are also discussed.

In the United States, highway cost allocation analysis has now become an integral part of a process of pricing and financing highway services in many states. Typically, the analysis is conducted to provide the following information: the cost responsibilities of various vehicle classes; the revenue contributions made by different vehicle classes; and the revenue-cost ratio of each vehicle class. The analysis results are useful for determining if different groups of highway users are paying their fair shares of cost responsibilities. They can also be used directly as the basis for formulating highway user-tax schedules. A number of recent publications illustrate these applications (*1–5*).

An important feature of highway cost allocation analysis is that results vary with changes in the following factors: expenditure pattern of the highway agency concerned; travel pattern of highway users; and composition of traffic streams in terms of vehicle type. These factors generally do not remain constant from year to year. They could differ significantly over a few years because of shifts in highway program emphases, changes in the age structure of highway facilities, and new developments in the socioeconomic environment. It is therefore important to conduct update analysis of highway cost allocation periodically to provide a valid basis for assessing the reasonableness and equity of highway user-tax structures.

An update analysis of highway cost allocation has recently been performed in Indiana. The salient features of the update analysis are described in this paper and the results of the study are presented. The important elements in an update analysis are highlighted, and the need to establish an efficient data base structure to enable update analysis to be completed within a reasonable time is stressed. A periodic update analysis of highway cost allocation can thereby be fiscally and practically feasible.

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BACKGROUND

The previous Indiana Highway Cost Study (*6*) was mandated in April 1983 and completed in two years. Its main objective was to determine if the tax payment of each user group matched its share of cost responsibility for highway expenditures. The study's major findings formed important input for the highway user-tax revisions enacted by the Indiana General Assembly in 1985.

The 1988 update analysis of highway cost allocation for Indiana was initiated in August and completed in less than six months. The main purpose of the analysis was to derive a new set of cost responsibilities and revenue-cost ratios for various vehicle classes based upon 1988 traffic composition and travel pattern data, and 1988 levels of expenditure and revenue. It also highlighted the data requirements and considerations important in an update analysis of highway cost allocation.

Figure 1, a flow diagram, shows the major steps in the cost allocation analysis. Three basic phases are identified in the flow diagram: defining of framework of analysis, collection and processing of data, and performing revenue contribution and cost responsibility analysis.

FRAMEWORK OF ANALYSIS

The overall framework of analysis in the update study was similar to that of the 1983 study. The same highway classification was adopted: Interstate urban, Interstate rural, State Route primary, State Route secondary, county road, and city street.

The classification of all vehicles in four categories—passenger car, bus, single-unit truck, and combination truck—also remained the same. However, some refinements in the subdivision of these categories were made in the update analysis to allow for more precise identification of certain vehicle types. These vehicle types were found to be of concern to several interest groups after the 1983 study results were published. Table 1 lists the 11 vehicle classes considered under the four main categories. These vehicle classes were further

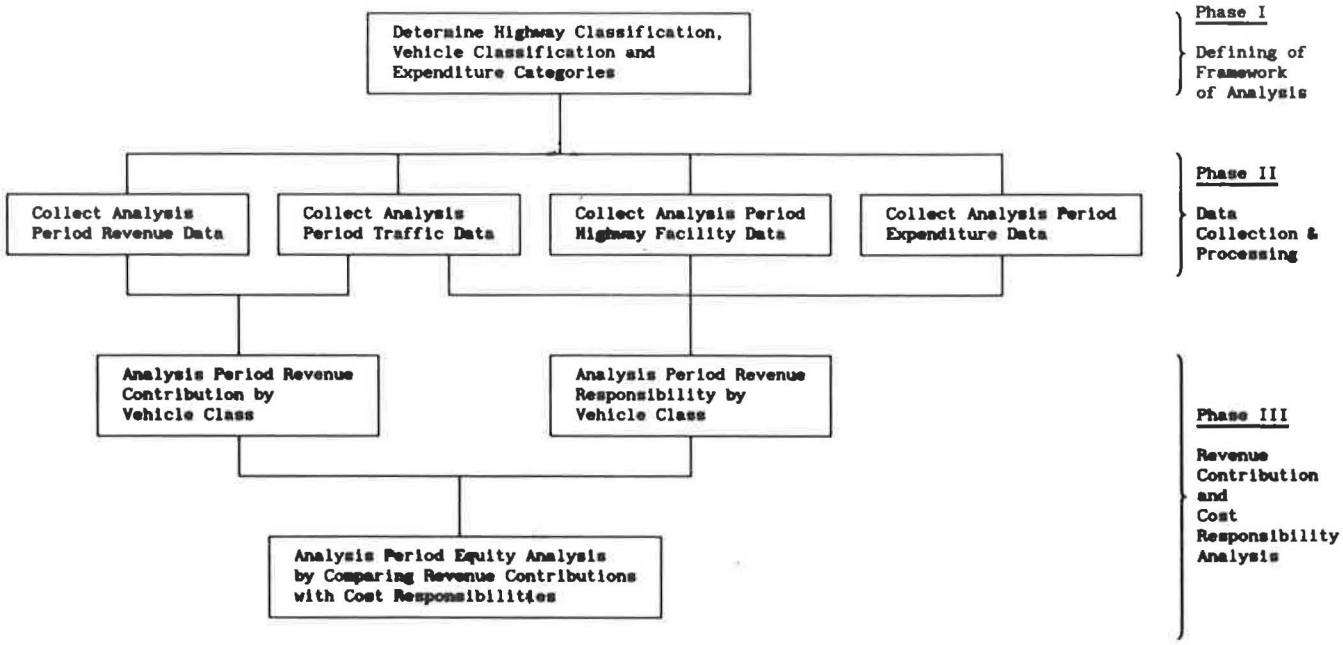

FIGURE 1 Flow chart for Indiana Highway Cost Allocation Analysis.

subdivided into vehicle groups on the basis of their operating vehicle weights. Table 2 shows the vehicle weight group classification adopted in the update analysis.

Expenditure categories were defined by six expenditure areas with several expenditure items under each as shown in Table 3. The dollar amounts of individual expenditure items were the costs used in the cost allocation analysis. These expenditure amounts were computed separately for each of the six highway classes. Such a detailed computation of highway expenditures was necessary because the relative shares of cost responsibility among vehicle classes varied from expenditure item to expenditure item and from highway class to highway class.

DATA COLLECTION AND PROCESSING

Four basic forms of data have been identified in Figure 1. The major requirements of each are discussed below.

Attributed Revenue

Table 4 shows the 1988 revenues contributed by Indiana highway users. Note that the main revenue sources were motor fuel taxes and vehicle registration fees. These two forms of tax (items 1, 2, 3, 4, 5, 8a, and 8b in Table 4) accounted for more than 90 percent of the total highway user revenue con-

TABLE 1 VEHICLE CLASSIFICATION

Main Category	Vehicle Class	Description
1. Passenger Car	1	Small Passenger Car
	2	Larger Passenger Car, Pickup and Van
2. Bus	4	Bus
3. Single Unit Truck	3	2-Axle Single Unit Truck
	5	3-Axle Single Unit Truck
	6	4-Axle Single Unit Truck
4. Combination Truck	7	3- or 4-Axle Combination Truck
	8	5-Axle Single Trailer Combination Truck
	9	5-Axle Multiple Trailer Combination Truck
	10	6-Axle Single Trailer Combination Truck
	11	6-Axle Multiple Trailer Combination Truck, or any Combination Truck with 7 or more Axles

TABLE 2 VEHICLE CLASS WEIGHT GROUP CLASSIFICATION

Vehicle Class	Weight Group	Weight in Pounds
1	1	All
2	1	All
3	1	<7500
3	2	7500-10,000
3	3	10,000-12,500
3	4	12,500-15,000
3	5	15,000-17,500
3	6	17,500-20,000
3	7	20,000-22,500
3	8	22,500-25,000
3	9	>25,000
4	1	All
5	1	<17,500
5	2	17,500-20,000
5	3	20,000-22,500
5	4	22,500-25,000
5	5	25,000-27,500
5	6	27,500-30,000
5	7	30,000-32,500
5	8	32,500-35,000
5	9	>35,000
6	1	All
6	2	<22,500
6	3	>22,500
7	1	<22,500
7	2	22,500-25,000
7	3	25,000-27,500
7	4	27,500-30,000
7	5	30,000-32,500
7	6	32,500-35,000
7	7	35,000-37,500
7	8	37,500-40,000
7	9	40,000-42,500
7	10	42,500-45,000
7	11	45,000-47,500
7	12	47,500-50,000
7	13	50,000 & Above
8	1	<22,500
8	2	22,500-25,000
8	3	25,000-27,500
8	4	27,500-30,000
8	5	30,000-32,500
8	6	32,500-35,000
8	7	35,000-37,500
8	8	37,500-40,000
8	9	40,000-42,500
8	10	42,500-45,000
8	11	45,000-47,500
8	12	47,500-50,000
8	13	50,000-52,500
8	14	52,500-55,000
8	15	55,000-57,500
8	16	57,500-60,000
8	17	60,000-62,500
8	18	62,500-65,000
8	19	65,000-67,500
8	20	67,500-70,000
8	21	70,000-72,500
8	22	72,500-75,000
8	23	75,000-77,500
8	24	77,500-80,000
8	25	80,000-82,500
8	26	82,500 & Above
9	1	<42,500
9	2	42,500-45,000
9	3	45,000-47,500
9	4	47,500-50,000
9	5	50,000-52,500
9	6	52,500-55,000
9	7	55,000-57,500
9	8	57,000-60,000
9	9	60,000-62,500
9	10	62,500-65,000
9	11	65,000-67,500
9	12	67,500-70,000
9	13	70,000 & Above
10	1	<40,000
10	2	40,000-60,000
10	3	>60,000
11	1	<40,000
11	2	40,000-60,000
11	3	>60,000

tribution. The diesel surtax was an add-on tax charged on all diesel fuel consumed in Indiana and collected from trucking companies. The motor carrier fuel use tax was collected from all commercial vehicles for the fuel not purchased in Indiana but consumed on Indiana roads. The International Registration Plan (IRP) was a reciprocity agreement on motor carrier registration fees. This fee was collected from interstate carriers of those states with which Indiana had a reciprocity agreement.

The revenue data records did not contain sufficient detail to give the individual revenue amount contributed by each of the vehicle weight groups listed in Table 2. It was therefore necessary to back-derive such information from the available aggregated revenue data. The methods of back-deriving vehicle weight group revenue contributions for fuel taxes and vehicle registration fees are described below.

The amount of fuel taxes paid by a vehicle depends on its total fuel consumption in the analysis period. Fuel consumption in turn is related to the total vehicle miles of travel and fuel efficiency. The total 1988 VMT (vehicle miles of travel) of each vehicle–weight group was first derived from traffic data. Fuel consumption in number of gallons consumed was computed next by dividing these VMT values by appropriate fuel efficiency factors. The number of gallons of fuel consumed was then multiplied by corresponding tax rates to give the desired tax revenue contribution for each vehicle weight group.

Truck registration fees in Indiana are collected on the basis of vehicle registration weight classification which is different from the vehicle operating weight classification defined in Table 2. Transformation between the two types of classification is not a straightforward process because a simple one-

TABLE 3 EXPENDITURE ITEMS BY EXPENDITURE AREA

Expenditure Area	Expenditure Item
Highway Construction	Pavement Right-of-Way Grading and Earthwork Drainage and Erosion Control Shoulder Miscellaneous Items
Structure Construction and Replacement	Bridge Superstructure Bridge Substructure Sign Structure Excavation and Backfill Miscellaneous Items
Structure Rehabilitation	Bridge Superstructure Bridge Substructure Sign Structure Excavation and Backfill Miscellaneous Items
Highway Rehabilitation	Pavement and Shoulder Right-of-Way Grading and Earthwork Drainage and Erosion Control Miscellaneous Items
Routine Maintenance	Pavement and Shoulder Drainage and Erosion Control Bridge Miscellaneous Items
Other Costs	Enforcement (policing) Weight Inspection Special Railroad Crossings Miscellaneous Items

to-one relationship between the gross operating weights and registered weights of a vehicle does not exist. Figure 2 shows the relationship between registered gross vehicle weight and operating vehicle weight.

A correspondence matrix may be developed from traffic loading data to facilitate computing registration fees paid by various vehicle operating weight groups. An example of a correspondence matrix is shown in Table 5. The elements in each row of the matrix are obtained from an appropriate weight distribution curve such as that illustrated in Figure 2. The registration fee contributions of individual vehicle weight groups in a vehicle class i are calculated from the following equations:

$$\begin{bmatrix} R_1 \\ R_2 \\ \cdot \\ \cdot \\ \cdot \\ R_m \end{bmatrix}_i = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix}_i^T \begin{bmatrix} r_1 \\ r_2 \\ \cdot \\ \cdot \\ \cdot \\ r_n \end{bmatrix}_i \tag{1}$$

that is

$$[R]_i = [a]_i^t [r]_i \tag{2}$$

where

R_j = registration fee contribution of vehicle weight group j, $1 \le j \le m$
m = total number of vehicle weight groups in vehicle class i,
r_k = registration fee paid by registered vehicle group k, $1 \le k \le n$
n = total number of registered vehicle groups in vehicle class i, and
a_{pq} = coefficient of correspondence matrix, $1 \le p \le n$, $1 \le q \le m$.

Traffic Data

Traffic data included traffic volume information, traffic stream composition, vehicle axle configuration, and operating axle weight information. These data were required for each of the six highway classes and were needed for computing traffic loadings in terms of equivalent single axle loads (ESALs) for the allocation analysis of pavement costs, developing correspondence matrices for revenue contribution calculation, and deriving the vehicle miles of travel (VMT) for each vehicle weight group within each highway class.

An in-depth examination of cost allocation analysis by the study team found that the outcomes of the analysis depend strongly on the relative magnitudes of VMT values of various vehicle weight groups and vehicle classes. The summary of cost allocation criteria presented in Table 6 clearly indicates why this is so. A detailed description of these criteria can be found elsewhere (*6–8*). Because the Σ ESAL value of each vehicle weight group can be considered as a factored sum of its VMT, the VMT distribution directly influences the cost allocation of almost every expenditure item.

Because of the importance of VMT information, county-by-county traffic volume data were obtained from the Indiana Department of Transportation (INDOT). The VMT of a given vehicle class was computed simply as the product of its total traffic volume counts in the analysis period and the highway mileage, as indicated below:

$$(\mathrm{VMT})_{ij} = 365(\mathrm{AADT})_{ij}(L)_j \tag{3}$$

where

$(\mathrm{VMT})_{ij}$ = VMT of vehicle class i on highway section j,
$(\mathrm{AADT})_{ij}$ = average annual daily traffic of vehicle class i on highway section j, and
$(L)_j$ = length of highway section j in miles.

The above computation was performed by highway class and vehicle class for each of the 92 Indiana counties. The statewide VMT values were obtained by summing the results from the 92 counties.

Expenditure Data

Most cost allocation studies have used actual expenditure instead of needed expenditure as the costs to be allocated. The pri-

TABLE 4 REVENUE SOURCES FOR FISCAL YEAR 1988

Revenue Sources	Revenue (in million dollars)
1. State Gasoline Tax	380.95
2. State Special Fuel Tax	82.80
3. Diesel Surtax	43.22
4. Motor Carrier Fuel Use Tax	6.89
5. Vehicle Registration, License and Title Fees	105.04
6. International Registration Plan	22.21
7. Oversize/Overweight Permits	3.53
8. Federal:	
a. Gasoline Tax	118.10
b. Diesel Tax	78.70
c. Heavy Vehicle User Fee	17.22
d. New Truck and Trailer Sale	23.26
e. Tire Tax	8.75
9. Local Option Tax	12.00
TOTAL	$902.67

mary reason for not using needed expenditure is the absence of fixed criteria about the level of highway needs that must be satisfied. On the other hand, the actual expenditure is the amount spent that can be directly related to the revenue contribution of the same period.

The actual highway expenditure for fiscal year 1988 was considered in the present update analysis. Only the expenditures supported by user revenue contribution were included in the cost allocation analysis. Expenditure data were collected separately for state highways, county roads, and city streets. A breakdown of the expenditures for the state highway and local road systems, supported with user revenue, by major cost categories for fiscal year 1988 is presented in Table 7.

Highway Facility Data

Physical characteristics of highway facilities (including roadway geometry, pavement structure thickness, and drainage

TABLE 5 EXAMPLES OF CORRESPONDENCE MATRIX BETWEEN VEHICLE REGISTRATION AND OPERATING WEIGHTS

Vehicle Class No. 7 Registration Weight (lbs)	Operating Weight Group of Vehicle Class No. 7												
	1	2	3	4	5	6	7	8	9	10	11	12	13
< 26,000	0.06	0.20	0.15	0.05									
26,000 - 29,999	0.30	0.20	0.20	0.15	0.10	0.05							
30,000 - 35,999	0.10	0.10	0.15	0.20	0.17	0.15	0.10	0.03					
36,000 - 41,999	0.06	0.06	0.09	0.12	0.15	0.15	0.15	0.11	0.08	0.03			
42,000 - 47,999	0.05	0.05	0.07	0.10	0.14	0.14	0.15	0.10	0.08	0.08	0.03	0.01	
48,000 - 53,999	0.04	0.05	0.06	0.10	0.14	0.14	0.15	0.10	0.09	0.08	0.03	0.02	
≥ 54,000	0.03	0.05	0.06	0.08	0.09	0.12	0.14	0.14	0.14	0.06	0.04	0.04	0.02

Notes: (1) Each value in table represents the fraction of given operating weight group vehicles present in the specified registration weight category.

(2) Vehicle Class No. 7 represents 3- or 4-axle combination trucks. Operating weight group details are given in Table 2.

(3) All empty cells have values of zero.

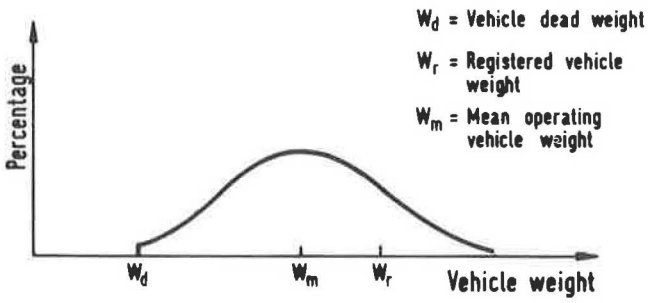

FIGURE 2 Schematic diagram showing the relationship between registered gross vehicle weight and operating vehicle weight.

features, etc.) were obtained from inventory records of the INDOT (Indiana Department of Transportation). The sources included highway inventory files, road life records, and construction reports. Pavement performance data were derived from the INDOT annual roadmeter roughness records.

REVENUE AND COST RESPONSIBILITY ANALYSIS

The derivation of revenue contributions by different vehicle classes and weight groups from aggregated revenue data has been explained earlier. These derived revenue contributions are useful for revenue-cost equity analysis by comparing them with corresponding vehicle class or weight-group cost responsibilities.

The cost responsibility of a vehicle group is affected by such factors as the type of pavement, the functional class of highway, and the nature of work for which individual expenditures were made during the analysis period. The breakdown of highway expenditures was documented by jurisdictional system, then by highway functional class, and finally by expenditure area and expenditure item. There were two jurisdictional systems in Indiana—state highway system and local highway system. For the state highway system, cost information was gathered by analyzing INDOT data files—road file records, construction reports, itemized cost estimate files, monthly

TABLE 6 COST ALLOCATION CRITERIA FOR EXPENDITURE ITEMS

Expenditure Item	Attributable Costs		Non-Attributable Costs	
	Proportion	Cost Allocator	Proportion	Cost Allocator
A. Highway Construction				
1. Pavement & Shoulder	100%	ESAL	-	-
2. Right-of-Way	100%	VMT & PCE-VMT	-	-
3. Earthwork	100%	VMT & PCE-VMT	-	-
4. Drainage	100%	VMT & PCE-VMT	-	-
5. Miscellaneous	-	-	100%	VMT
B. Highway Rehabilitation				
1. Pavement & Shoulder	66 - 98%	ESAL	2 - 34%	VMT
2. Right-of-Way	100%	VMT & PCE-VMT	-	-
3. Earthwork	100%	VMT & PCE-VMT	-	-
4. Drainage	100%	VMT & PCE-VMT	-	-
5. Miscellaneous	-	-	100%	VMT
C. Highway Maintenance				
1. Pavement & Shoulder	66 - 98%	ESAL	2 - 34%	VMT
2. Right-of-Way	-	-	100%	VMT
3. Drainage	-	-	100%	VMT
4. Miscellaneous	-	-	100%	VMT
D. Bridge Construction Replacement & Rehabilitation				
1. Superstructure	100%	Axle Load		
2. Substructure	25 - 35%	Axle Load	65 - 75%	VMT
3. Drainage	-	-	100%	VMT
4. Excavation	-	-	100%	VMT
5. Miscellaneous	-	-	100%	VMT
E. Bridge Maintenance				
1. Roadway	66 - 98%	ESAL	2 - 34%	VMT
2. Structure			100%	VMT
3. Miscellaneous			100%	VMT

Notes: ESAL = Equivalent single axle load
VMT = Vehicle miles of travel
PCE = Passenger car equivalent

TABLE 7 EXPENDITURE SOURCES FOR FISCAL YEAR 1988

A.	State Highway System (Interstate, Primary and Secondary)	
1.	Highway Construction	$201,229,460
2.	Highway Rehabilitation	$131,440,745
3.	Highway and Bridge Maintenance	$142,495,591
4.	Bridge Construction and Replacement	$ 13,070,833
5.	Bridge Rehabilitation	$ 64,586,263
	Total (State Highway System)	$552,822,892
B.	Local Road System (County Road and City Street)	
1.	Road Construction	$ 29,968,730
2.	Road Rehabilitation	$ 60,830,560
3.	Road and Bridge Maintenance	$162,096,710
4.	Bridge Construction and Replacement	$ 526,500
5.	Bridge Rehabilitation	$ 26,003,500
	Total (Local Road System)	$279,426,000
	Total (State and Local)	$832,248,892

expenditure files, and routine maintenance files. For the local highway system, the corresponding data were derived by sampling records from a number of counties and cities, as well as INDOT local road inventory files and local assistance project reports. The total state highway system expenditure was divided into three functional classes—Interstate highways, state primary, and state secondary routes. The total expenditures on the local highway system was classified into county roads and city streets. It was necessary to perform cost responsibility analysis for each expenditure item by highway class.

The total cost responsibility of a vehicle group was obtained by summing its cost responsibilities over individual expenditure items. This concept of step-by-step aggregation of cost responsibility is illustrated in Figure 3, which depicts the flow of computation of statewide cost responsibilities for state highways. The computation began within each block where the cost responsibilities for individual expenditure items were computed separately and then aggregated for different vehicle weight groups. Next, cost responsibilities of Interstate, State Primary, and State Secondary were aggregated by vehicle weight group for construction, rehabilitation, and maintenance expenditures, respectively. Finally, aggregation of cost responsibilities was performed to combine the three expenditure areas and give the vehicle weight group cost responsibilities for state highways.

The same cost responsibility calculation and bookkeeping aggregation process was repeated for city streets and county roads, and for bridges. The computation involved in determining the overall statewide cost responsibilities of vehicle weight groups is given in Figure 4. The above computation can be represented as follows:

$$F_{ij} = \sum_k \sum_l \sum_m \sum_n (D_{ijklmn} \times E_{klmn}) \tag{4}$$

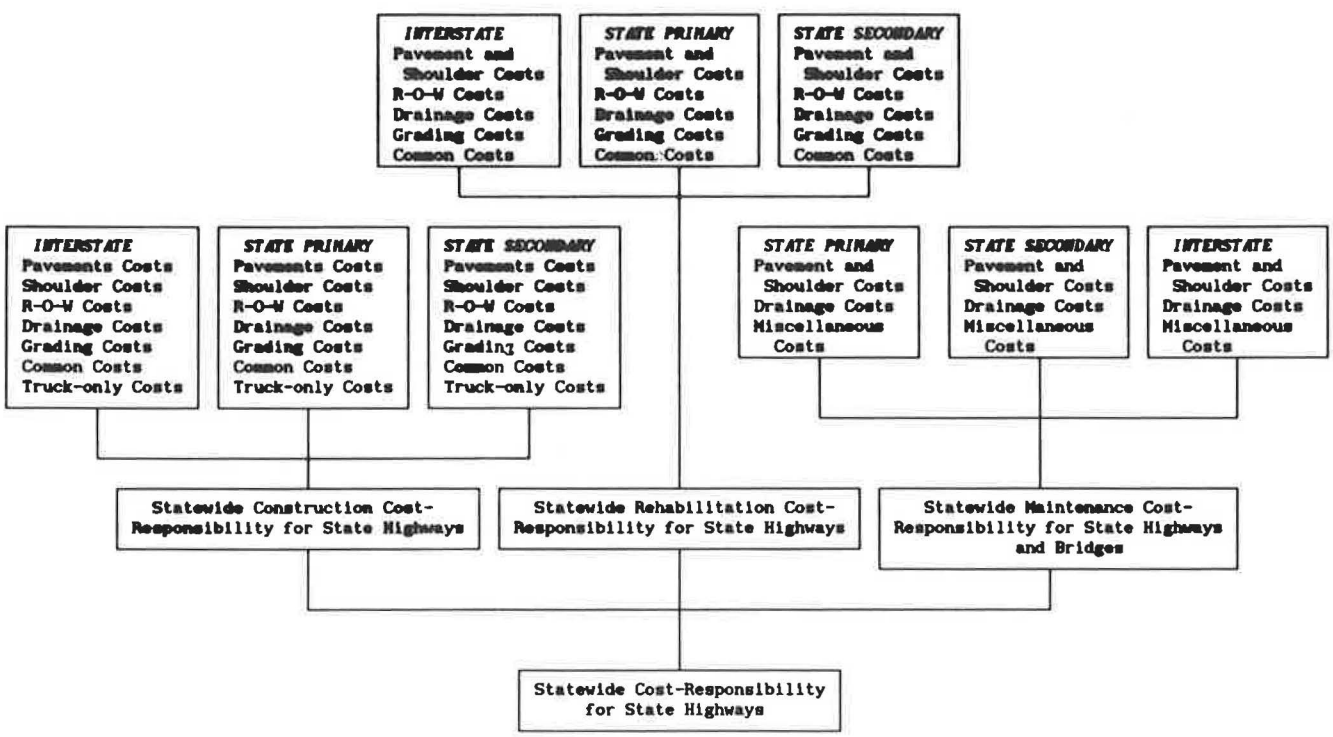

FIGURE 3 Computation of statewide vehicle weight group cost responsibilities for state highways.

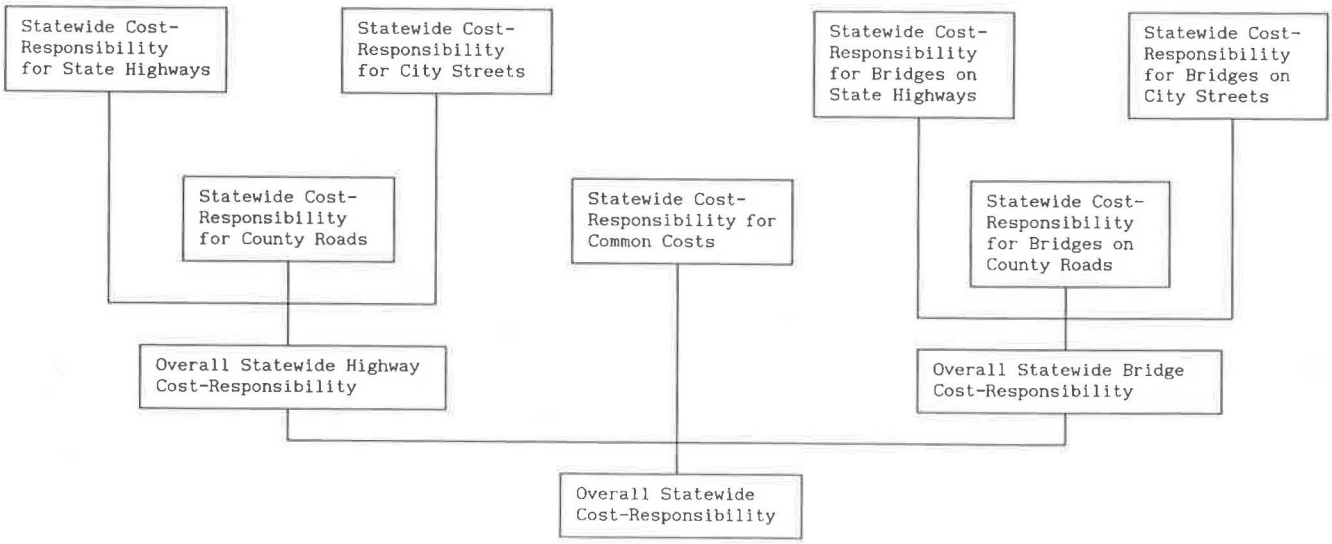

FIGURE 4 Computation of overall statewide vehicle weight group cost responsibilities.

where

F_{ij} = cost responsibility of vehicle weight group i in vehicle class j, dollars:

D_{ijklmn} = cost responsibility of vehicle weight group i in vehicle class j on pavement type l of highway class k for expenditure item n of expenditure area m, percent and

E_{klmn} = analysis period expenditure amount of expenditure item n of expenditure area m for pavement type l of highway class k, dollars.

The ranges of indices i and j were determined from Tables 1 and 2, and those of indices m and n from Table 3. The index k ranges from 1 to 6, and l from 1 to 3 to represent flexible, rigid, and overlaid pavements.

It can be noted from Figure 4 that user group cost responsibilities for state highways, county roads, and city streets were kept separated up to the final step. These highways were constructed and are maintained by different jurisdictional agencies that keep separate cost accounts and records.

In the update analysis, the methodologies for computing cost responsibilities (i.e. values of D_{ijklmn} in Equation 4), were the same as those developed in the 1983 study. Details of the methodologies are given elsewhere (*6–9*).

Revenue-Cost Equity Analysis

The widely accepted concept of equity in highway cost allocation analysis is one based on revenue-cost ratios of user groups. This concept has been particularly useful for analysis and formulation of highway user taxes because it directly relates the tax payment of individual highway user groups to their respective cost responsibilities.

The revenue-cost ratio of a user group (or vehicle weight group) may be obtained by comparing its revenue contribution with its cost responsibility for highway expenditures. It is usually calculated by dividing the percentage revenue contribution of the vehicle weight group by its percentage cost responsibility:

$$\frac{\text{Revenue}}{\text{cost}}\text{ratio} = \frac{\left(\dfrac{\text{revenue contribution}}{\text{total user revenue}}\right) \times 100\%}{\left(\dfrac{\text{cost responsibility}}{\text{total highway expenditure}}\right) \times 100\%} \quad (5)$$

A revenue-cost ratio of unity implies that the user group concerned is paying its fair share of cost responsibility. A revenue-cost ratio greater than unity indicates overpayment, and a ratio smaller than unity means underpayment.

RESULTS AND FINDINGS

Results of the 1988 update study are summarized in Table 8. Only the results for the 11 vehicle classes are presented. Detailed results for all vehicle weight groups are given elsewhere (*10*).

Cost Responsibility by Vehicle Class

All the cost responsibilities reported in Table 8 are expressed in terms of percentages of total highway expenditure in the analysis period. As explained above, this form of expressing cost allocation analysis results offers a direct, easily understood comparison with vehicle revenue contribution.

The overall cost responsibilities in fiscal year 1988 were 44.60 percent, 2.20 percent, 14.30 percent, and 38.90 percent for passenger cars, buses, single-unit trucks, and combination trucks, respectively. Comparing these figures with their corresponding percentage VMT values, it is apparent that the passenger car was the only user group that had a smaller numerical value of percentage cost responsibility than its percentage VMT value. This was because the other three categories of user groups had larger PCE (passenger car equivalent) values, heavier vehicle weights, and very much higher ESAL factors. As can be seen from Table 6, vehicle weight was the main cost allocator for bridge superstructure and

TABLE 8 SUMMARY OF RESULTS OF 1988 INDIANA UPDATE ANALYSIS OF HIGHWAY COST RESPONSIBILITY AND REVENUE CONTRIBUTION

Vehicle Category	Vehicle Class	Percentage VMT	Percentage Cost Responsibility	Percentage Revenue Contribution	Revenue-Cost Ratio
Passenger Car	1	32.50	13.70	14.68	1.071 (0.743)
	2	55.92	30.90	42.82	1.385 (1.363)
		88.42	44.60	57.50	1.289 (1.235)
Bus	4	0.57	2.20	2.00	0.909 (0.830)
Single Unit Truck	3	1.91	4.90	5.99	1.222 (1.185)
	5	1.00	3.40	3.55	1.044 (0.848)
	6	0.34	6.00	5.46	0.910 (1.490)
		3.26	14.30	15.00	1.050 (1.133)
Combination Truck	7	1.30	6.10	4.24	0.695 (0.505)
	8	5.65	29.00	18.65	0.643 (0.625)
	9	0.22	0.70	0.61	0.871 (0.981)
	10	0.49	2.30	1.50	0.652 (-)
	11	0.09	0.80	0.50	0.625 (0.468)
		7.75	38.90	25.50	0.655 (0.621)

Note: Revenue-Cost ratios in parentheses are results of 1983 Indiana Cost Allocation Study.

substructure costs, while ESAL and PCE were important in allocating pavement construction, maintenance, and rehabilitation costs.

Revenue Contribution by Vehicle Class

The revenue contributions of individual vehicle classes presented in Table 8 are expressed as percentages of the total revenue collected in fiscal year 1988. The revenue contributions made by passenger cars, buses, single unit trucks, and combination trucks were 57.50 percent, 2.00 percent, 15.00 percent, and 25.50 percent, respectively. It can be noted that the revenue contributions had the same general trend as the cost responsibility. For example, the three vehicle classes with the highest revenue contributions were Vehicle Class 2 (large cars), Vehicle Class 8 (five-axle combination trucks), and Vehicle Class 1 (small cars). The same trend was also observed in cost responsibility figures.

Equity by Revenue-Cost Ratios

On the basis of the revenue-cost ratios computed in Table 8, the update analysis revealed that passenger cars, including pickups and vans, were overpaying by about 28 percent, while heavy combination trucks were underpaying by as much as 35 percent. Single-unit trucks as a group overpaid slightly, whereas buses underpaid by about 9 percent. The net effect was that passenger cars and single unit trucks subsidized buses and combination trucks.

The results also revealed a considerable inequity within each vehicle class. For example, within the vehicle class of single-unit trucks, the revenue contribution by three-axle single-unit trucks was almost equal to its cost responsibility (revenue-cost ratio = 1.044), but two-axle and four-axle single-unit trucks overpaid and underpaid by about 22 percent and 9 percent, respectively. For passenger cars, there was also a large difference in the extent of overpayment between the two vehicle classes that composed this vehicle category. Large cars overpaid by about 39 percent while small cars overpaid by only 7 percent. The underpayment of combination trucks was consistent among all vehicle classes within this category, although the extent of underpayment varied among the classes.

The revenue-cost ratios obtained from the 1983 cost allocation study are also presented in Table 8 for comparison purposes. The following differences between the 1988 update analysis results and the 1983 study results can be observed: Considering the four major vehicle categories, a general improvement in overall revenue-cost equity was achieved in 1988. Discrepancies of revenue-cost equity among the vehicle classes in each vehicle category have been greatly reduced. These findings confirmed the beneficial effects of the tax structure revision implemented in Indiana as a result of the 1983 study (*3*).

KEY ELEMENTS IN COST ALLOCATION UPDATE ANALYSIS

Based upon the experience and findings of the 1988 highway cost allocation update study in Indiana, the following key elements have been identified as important for implementing a scheme that allows efficient update cost allocation analysis to be conducted periodically.

Efficient Links to Other Data Bases

A large proportion of the data required for cost allocation is available in existing data bases maintained by different depart-

ments of a highway agency. Data collection efforts in an update cost allocation study could be considerably reduced by developing a data base that will automatically receive pertinent information from existing data bases in the highway agency.

Because most available data from other data bases are usually not recorded in a format directly useable in a cost allocation analysis, it is desirable that some processing of this information be performed before storing it in the cost allocation data base. Using the acquisition and storage systems for highway and transportation data in Indiana as the reference, Figure 5 shows the information links required between a cost allocation data base and existing information systems. Figure 5 further illustrates that much of the information required in the data collection phase (see Figure 1) in an update cost allocation analysis could be made readily available with the establishment of such a data management system.

The use of a cost allocation data base would considerably shorten the time required to perform a full-scale update cost allocation analysis. A data base would make periodic assessments of cost responsibility and of revenue contribution practical and feasible. It is estimated that, with the aid of an efficient data base, an update analysis could be completed within three months. The constantly updated information in the cost allocation data base would also enable one to determine if there have been significant shifts in expenditure pattern, changes in travel pattern, or changes in revenue contribution that warrant an update analysis of cost allocation.

Acquisition of Critical Data

Certain input information to cost allocation analysis cannot be obtained with sufficient detail and accuracy from existing data bases. Such data include VMT information on various highway functional classes by vehicle weight group, and distribution of the magnitudes of operating axle load for each vehicle weight group. The usefulness of the results of a cost allocation analysis depends critically on the quality and accuracy of these data. The VMT input has direct influence on the cost responsibility computation of almost every expenditure item. Reliable axle load input is crucial for allocating bridge and pavement costs. Operating axle load information forms the basis to derive correspondence matrices between vehicle registration and operation weights. Apparently, a detailed field survey is necessary for collection of reliable input data when an update cost allocation analysis is to be performed.

Updating of Cost Allocation Methodology

Several areas exist in cost allocation study in which the limits of current knowledge do not allow technical analyses to be carried out fully. Subjective judgments are involved in allocating some expenditure items. One of the most controversial topics is undoubtedly the determination of attributable and

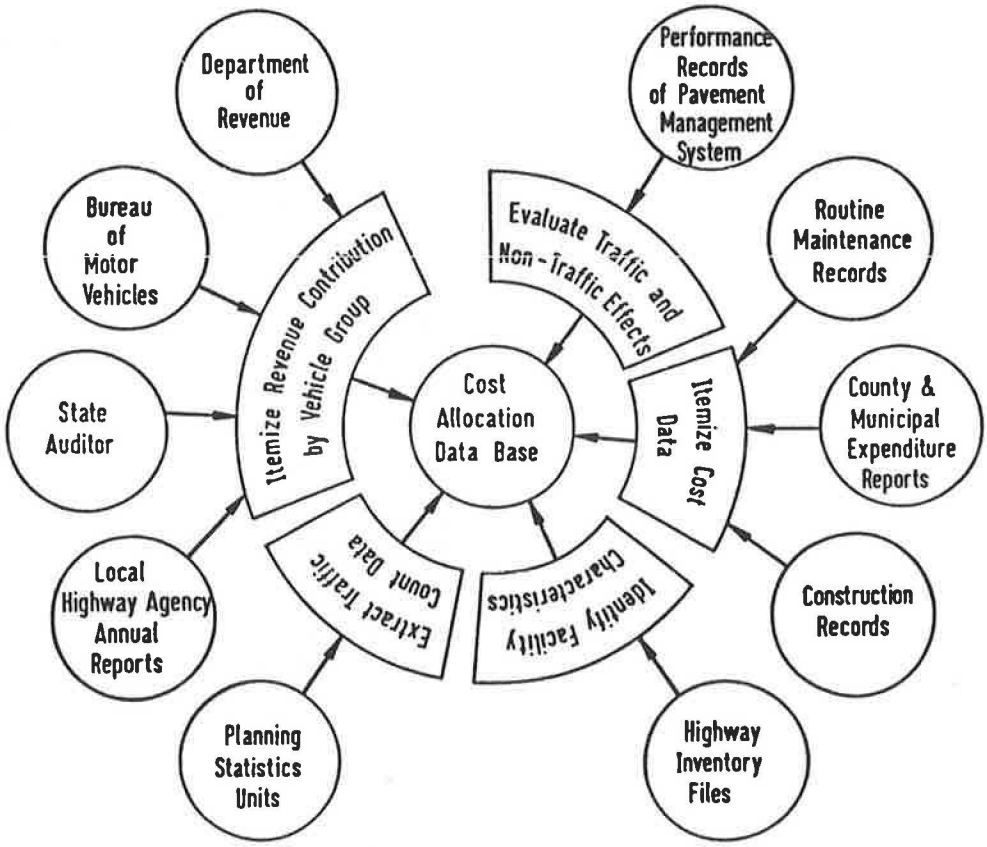

FIGURE 5 Links between cost allocation data base and other data storage systems.

non-attributable components of an expenditure item. Non-attributable costs refer to expenditures that result from non-traffic causes such as the action of environmental forces, and expenditures incurred based upon aesthetic or political considerations. These costs cannot be attributed to any particular user groups. Attributable costs are those that can be attributed to one or more highway user groups. Further research on traffic and non-traffic-related effects on factors such as pavement performance and bridge deterioration is required to help identify the relative proportions of attributable and non-attributable costs. Allocation of safety improvement costs is another area in which clear-cut procedures are not available. Updating of cost allocation methodology in these areas should be carried out as more information becomes available.

CONCLUSIONS

A detailed description of the procedures involved in the 1988 update analysis of the cost allocation study in Indiana has been presented. Results and findings of the analysis are presented and discussed. Based on the analysis conducted, several key elements involved in an update analysis of highway cost allocation were identified. The experience derived from the study has shown data collection and processing to be the most crucial phase in an update cost allocation analysis. It was the phase that had direct impact on the outcome of the analysis. It was also the phase that required the most resources and time.

Because cost allocation is an important element of the process of pricing and financing highway services in many states, and because the dynamic nature of the problem makes periodic updating of such analysis desirable, the authors stress the need to establish a data base consisting of relevant information extracted from other systems that exist in a typical highway agency. This would enable periodic cost allocation update analysis to be conducted efficiently and would help provide state highway agencies with a tool to formulate financing schemes to meet highway and transportation needs.

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