

AASHO Road Test Findings Applied to State Highway Cost Allocation Studies

JAMES M. SMITH and REED H. WINSLOW, respectively, Associate and Highway Engineer, Wilbur Smith and Associates, Columbia, South Carolina

Results of the pavement experiments on the AASHO Road Test have been applied in allocating cost responsibility to motor vehicle users in comprehensive studies of highway finance in Kansas and South Dakota. The Road Test formulas were used in apportioning pavement costs among vehicle classes in the incremental solution of the allocation problem. The incremental solution, with other allocation solutions and tax data, guided the formulation of recommendations on user taxation.

The Road Test equations were used as a model for predicting performance under traffic of typical pavement structure designs. These designs reflected local conditions and costs in several areas of each State. Pavement costs reported in highway needs studies were then allocated to users in proportion to their influence on pavement performance. The pavement allocation was a relatively small part of the total user responsibility, but for the heavier trucks it was a very significant part.

The incremental solution tended to assign greater responsibility to light vehicles and less to heavy trucks compared with the cost-function solution or the average of the vehicle-mile and ton-mile solutions. In formulating recommendations, the incremental solution was particularly useful because it reflected the influence of vehicle type and axle configuration. The Road Test equations assign less responsibility to tandem axle units than to single axles of similar weight.

•THE AASHO Road Test has commanded the attention of the highway fraternity for several years. The areas of study and experiment touched on many technical aspects of highway management. One aspect, which has been foremost in the minds of planners and administrators, is the influence of the pavement experiments on vehicle size and weight and on allocation of cost responsibility among classes and weights of vehicles. The AASHO Highway Transport Committee (1) in its "Statement of Fundamental Principles, Project Elements, and Specific Directions," emphasized the importance of the Road Test in developing bases for taxation and guidance on economics of vehicle size and weight.

During 1962, comprehensive studies of highway finance on all road systems—State, county, and municipal—were made in Kansas and South Dakota. These were undertaken in conjunction with highway needs studies and included the allocation of responsibility for costs in the estimates of 20-year needs. Agreements for the conduct of the studies specified that an incremental analysis would be made using the results of the AASHO Road Test, as they apply to local conditions. Results of these studies have been published in reports presented to the South Dakota Highway Commission (2) and the Legislative Council and the State Highway Commission of Kansas (3).

The problem of highway cost allocation, or distribution of responsibility, divides naturally into two phases. The first phase is the assignment of gross responsibility between the general public, commonly referred to as the nonuser, and the motor vehicle users. In reality, these two categories are not exclusive but, from the taxation

viewpoint, they constitute sources of revenue which require distinct tax structures. The "earnings-credit" method was used to allocate total highway program costs into shares to be borne by the general public and the motor vehicle users. By this method, approximately 70 percent of the total program was assigned to the motor vehicles (user responsibility amounts to 73.2% in Kansas and 69.0% in South Dakota) a result which is generally consistent with solutions based on 20-year needs in other States—for Mississippi, 68 percent user responsibility (4); for Missouri, 60 percent (5); for Ohio, 69 percent (6).

USER COST ALLOCATION

The portion of program responsibility assigned to the highway user must be further allocated to vehicle-type and weight classes so that a comparison can be made between the tax structure and responsibility. Four solutions of the cost allocation were made in each study to provide maximum guidance for recommendations on user taxation, realizing that all such solutions must be tempered by peculiar local conditions, precedents, and other factors. These four allocations were the incremental, the cost function, the vehicle-mile, and the ton-mile methods. Because of its sound, logical basis, the incremental analysis was assumed to provide one of the most valid solutions. At the same time, it was recognized that certain arbitrary decisions were necessary in all methods and that more experience was available on the other methods because they have had wider applications.

In the two studies, procedures and decisions were kept uniform. Needs data were reported on the same format in each State; the similarity of terrain and construction practices further aided uniformity (7, 8). Adequate traffic data were available but differences in form, arising in part from the different registration fee bases, made it necessary to devise separate traffic analysis procedures for each State. These differences in traffic data are carried over to the presentation of results related to gross vehicle weights since Kansas reported maximum gross weight for each registration fee group and South Dakota reported the owners statement of gross vehicle weight and related it to chassis weight.

Throughout the study, guidance was derived from procedures used in the Federal Highway Cost Allocation Study (9, 10, 11). Several conferences were held with personnel of the U. S. Bureau of Public Roads and every effort was made to keep the State study procedures consistent with those used by the Bureau.

Cost-Function, Vehicle-Mile, and Ton-Mile Solutions

The cost-function solution distributes costs in categories according to several measures of use. All items of cost are considered and a decision is made as to the measure of use that would be most likely to influence the magnitude of the cost item. In these studies, the selected measures of use were numbers of vehicles, axle-miles of travel, and ton-miles of travel. Each distinct item of cost was assigned to one of these functions or proportioned between two of them.

The vehicle-mile and ton-mile solutions allocate all cost according to the respective measures of highway use. Neither is generally regarded as an adequate solution of the user cost allocation problem, but both do establish limits of total responsibility for each class. An allocation based on a compromise or proportioning between the two provides a useful reference point when evaluating other solutions. In these studies, equal weight was given to each of these methods and the results were presented as a single compromise solution.

Incremental Solution

The underlying concept of the incremental method of cost allocation is that each vehicle should participate in all increments of costs incurred in building a road adequate for that vehicle. Increments of costs made necessary by larger or heavier vehicles should be borne by these vehicles only. All vehicles participate in the first increment of costs, but the lighter vehicles are not required to contribute to the successively

higher increments. In theory, this assigns responsibility according to the costs of providing highway facilities which each vehicle has occasioned. In practice, much depends on the judgment of the analyst in selecting methods of incrementing costs, of allocating costs within increments, and in assigning gross costs to the several categories which are analyzed by the various methods. For example, in the treatment of pavements, a critical decision is necessary on what minimum thickness of surface will be incremented. In comprehensive State studies there may be many miles of secondary roads with surfacing at or near this cutoff. Similarly, decisions are necessary on which types of work changed structural characteristics and which merely rehabilitated them.

Four categories of costs were established for distribution in the incremental analysis: pavement, structures, grading and drainage, and miscellaneous. Each category was treated differently in the analysis so that a total assignment of costs by four methods was necessary.

The cost category for which the AASHO Road Test pavement experiment results were used included all costs for base and surface on reconstruction or new construction where the surface type was classed as high or intermediate in the needs study. These classes include all rigid pavements as well as all flexible surfaces greater than one inch in thickness on a prepared base. Design engineers in each State prepared typical designs for these surface types. Typical designs and associated cost estimates were prepared for each system classification and highway district so that the analysis would reflect the influence of soil conditions, material availability, and traffic composition.

Results of the Road Test indicate clearly that, although rigid and flexible pavement performance could be described by the same general formulas, different parameters were necessary to describe the behavior under traffic. It was, therefore, necessary to analyze both types of pavement separately and sum the responsibility by vehicle types. Needs data indicated the class of pavement, either high or intermediate, and State construction practice provided the basis for proportioning needed mileage at each class to rigid and flexible types. Traffic data, including traffic counts, loadometer surveys, vehicle registration records, and truck-use questionnaires, were obtained and processed to determine the frequency of application of axle loads in six increments of weight as related to vehicle type and weight. Frequency distributions were developed for each basic pavement design and for each highway district and road system.

Analysis of the pavement designs, using Road Test equations, established the proportion of the pavement structure that should be attributed to each of the increments of axle weight. The proportion of effective pavement structure in each increment was assumed to be directly proportional to construction costs and was distributed to each vehicle type according to the frequency of occurrence of that weight. Responsibility of each vehicle type was then summed and the total cost responsibility for each vehicle of a given type was redistributed according to frequency of occurrence of axle loads in the gross weight groups of the vehicle type.

The second group of costs consisted of those associated with construction of new bridges either on the same or on new locations, less the general public's share of these costs. All structure costs were incremented in proportion to the cost of providing bridges carrying H5, H10, H15, H20, and H20-S16 design loadings, conforming to AASHO bridge specifications. Several typical spans and structural types were investigated and weighted average costs were developed. Loadometer data were used to develop frequency of occurrence of gross operating weights for each vehicle type. Table 1 gives the assignment of vehicle-operating weights to increments. Allocation of costs within the increments was made in proportion to vehicle-miles of travel. The AASHO Road Test bridge experiments were not a factor in the incremental analysis of structure costs.

The third group of costs included grading and drainage costs on widening, reconstruction, and new construction projects, again excluding the general public's share. The basis for incrementing these costs was the assumed effect of vehicle size on pavement and shoulder width. Only vehicles having observed operating weights of more than 10,000 lb shared grading and drainage costs associated with provision of the outside $\frac{1}{2}$ ft of surface and 2 ft of shoulder. Analysis of typical design cross-sections

TABLE 1
INCREMENTS OF STRUCTURE COSTS

Increment	AASHO Design Loading	Vehicle-Operating Weight (lb)	
		Single Unit	Combination
First	H5	0 - 10,000	--
Second	H10	10,000 - 20,000	0 - 27,000
Third	H15	20,000 - 30,000	27,000 - 40,000
Fourth	H20	30,000 - 40,000	40,000 - 54,000
Fifth	H20-S16	Over 40,000	Over 54,000

showed that approximately 9 percent of the total grading and drainage quantities were required because of this added width. Therefore, a percentage of these costs was allocated to vehicles having observed operating weights over 10,000 lb. The remaining 91 percent of the costs were distributed to all vehicles in proportion to travel.

All other costs making up the total motor vehicle user responsibility fall into the fourth category which does not lend itself to incremental treatment. These costs include such items as right-of-way, gravel and light bituminous surfaces, resurfacing, structure reconditioning, maintenance, and administration of highway and motor vehicle regulatory activities. These costs were distributed to all vehicles in proportion to vehicle-miles of travel.

USE OF ROAD TEST EQUATIONS

The equations derived from the pavement experiments of the AASHO Road Test (12) describe the relationship between the number of applications of uniform axle loads and pavement performance of change in serviceability. The model of pavement performance which was selected as most appropriate for expressing results of the experiment is the general form:

$$p = c_0 - (c_0 - c_1)(W/\rho)^\beta \quad (1)$$

in which

- p = serviceability trend value;
- c_0 = initial serviceability index;
- c_1 = serviceability index at which a test section was considered out of test;
- W = accumulated axle load applications at time p is observed; and
- ρ and β = functions of design and load.

By defining a function of serviceability,

$$G = \log (c_0 - p) - \log (c_0 - c_1) \quad (2)$$

the basic model is expressed as

$$G/\beta = \log W - \log \rho \quad (3)$$

In applying these equations, it was necessary to convert to mixed traffic having a wide range of axle loads and axle configurations. Also, the concept of serviceability had to be related to levels of tolerability on public highways. On the Road Test, pavement sections remained in the test until they reached a serviceability trend value of 1.5, measured on a scale of 5.0 points. Initial serviceability, the level before traffic started, averaged 4.5 for rigid pavements and 4.2 for flexible pavements (12). For the Kansas and South Dakota studies, it was decided that 2.0 points better described the minimum conditions that could be considered tolerable. It was assumed that average initial serviceability would be the same as that measured on the Road Test. Because this assumption may not be entirely tenable, it might be better to say that during

their useful life, a decline in serviceability of 2.2 to 2.5 points was assumed.

Procedures developed by the U. S. Bureau of Public Roads were used in solving the equations for mixed traffic conditions (13). Though this method uses the "equivalent applications approach" to mixed traffic, which has some acknowledged theoretical deficiency (14), it is felt that the quality of the solution is consistent with the precision of the data on traffic and the generalized nature of the typical designs and costs. In the analysis of loadometer data for this procedure, axle load frequency distributions were developed for each type of vehicle using single axle equivalents for tandem axles. Equivalency factors of 0.54 for flexible pavements and 0.62 for rigid pavements were used. Frequency was expressed in terms of proportion of single axles and equivalent tandem axles falling in six weight groups: 0 to 3 kips, 3 to 7 kips, 7 to 12 kips, 12 to 16 kips, 16 to 20 kips, and over 20 kips. For each axle weight group, the summation of frequency of occurrence times numbers of the appropriate vehicle type was accumulated and reduced to a series of C-factors or proportional parts for use in the incremental analysis of each typical design.

The Road Test equations were solved and tabulated for each 0.05-in. variation in thickness in the working range of effective depth D. This range is from 1 to 7 in. for flexible pavements and 4 to 10 in. for rigid pavements. As used in the Road Test equations, the effective thickness is given for rigid pavements by

$$D = D_1 \quad (4)$$

and for flexible pavements by

$$D = 0.44 D_1 + 0.14 D_2 + 0.11 D_3 \quad (5)$$

in which

D_1 = surface thickness,
 D_2 = base thickness, and
 D_3 = subbase thickness.

It was not intended to increment below the lower limit of the working range but in the analysis it was never necessary to apply this criterion.

The Road Test equation solutions gave the number of applications, R, of a 3-kip axle which had the same influence of pavement performance as one axle in each heavier axle weight group, an equivalence that varies with D. Also they were solved for the ratio of the number of applications of a 3-kip axle load to reach the selected tolerable serviceability index over the number of applications to reach an index of 1.5 during the pavement experiment. The logarithm of this ratio is the term G. Although only values for the 3-kip axle load were used in the incremental solution, it was necessary to evaluate the term for each load in solving for R. Table 2 gives the ranges of values for these functions, within the working ranges of D. Values for $R_{22.2}$ (the R factor for axle loads over 20 kips) were required infrequently and were not developed for the entire range of D.

To facilitate the solution for increments of pavement thickness, a value K was calculated for each design, which was a function of pavement thickness, change in serviceability, and traffic for the initial D, as follows:

$$K = A_1 \log (D + 1) + G/\beta_3 - \log \Sigma CR \quad (6)$$

in which

A_1 = constant determined by pavement type and by use of unweighted (seasonally) traffic data equal to 9.36 for flexible pavements and 7.35 for rigid pavements (12).

Traffic is expressed as the summation of products of C and R for each axle weight group. In successive trials, D was re-evaluated using K and revised values for G/β_3 and ΣCR .

For each lesser increment, a trial D was selected; C for the highest axle load group of the preceding increment was added to the next lower C, R values for trial D were determined, summation of C times R was re-evaluated, and a calculated D was deter-

TABLE 2
TYPICAL FACTORS DEVELOPED FROM ROAD TEST EQUATIONS

Effective Pavement Structure (in.)	$\log(W/\rho)^1$	R_7^2	R_{12}	R_{16}	R_{20}
(a) Flexible Pavements					
1.00	-0.14939	21.497	205.18	732.81	2003.1
2.00	-0.20985	23.635	200.65	676.45	1803.0
3.00	-0.21942	26.312	235.14	761.96	1941.7
4.00	-0.22142	27.198	261.56	874.90	2218.1
5.00	-0.22199	27.471	273.48	948.88	2470.1
6.00	-0.22219	27.573	278.57	986.17	2629.0
7.00	-0.22227	27.613	280.73	1003.70	2713.4
(b) Rigid Pavements					
4.00	-0.07871	23.813	202.84	677.45	1781.0
5.00	-0.07908	24.387	216.60	703.92	1810.3
6.00	-0.07915	24.536	225.95	745.19	1883.7
7.00	-0.07917	24.576	229.64	775.43	1980.8
8.00	-0.07918	24.584	230.91	789.80	2053.0
9.00	-0.07918	24.583	231.33	795.62	2090.0
10.00	-0.07918	24.586	231.50	798.15	2108.8

¹Logarithm to base 10 of ratio of number of axle load applications, W , necessary to cause a given loss in serviceability over number of applications, ρ , causing a loss in serviceability which would remove a test section from road test experiment, also referred to as G/β .

²Ratio R_x is number of applications of a 3-kip axle load divided by the number of applications of an axle load x kips causing the same loss in serviceability.

mined. Successive trials were run until the assume D equaled the calculated D . Differences in D -values determined for successive axle weight groups established the increments of pavement thickness that were allocated only to axles heavier than those used in calculating the lesser value.

SIGNIFICANCE OF ROAD TEST EQUATIONS IN INCREMENTAL ANALYSIS

A comparatively small portion of the total user responsibility was allocated by the incremental analysis of pavements using AASHO Road Test equations. For example, in Kansas 17 percent of costs were included in the pavement category and 61 percent in the miscellaneous category which was allocated equally to all classes of vehicles in proportion to travel. In South Dakota, a similar relationship prevailed with 23 percent of responsibility in pavement costs, an amount that is influenced by a high proportion of user responsibility for the State highway system where most high and intermediate-type pavements occurred. The structure, and grading and drainage cost categories each represented a smaller proportion than pavements of the total user responsibility.

For heavier vehicles, the pavement allocation has a much greater effect on responsibility. This could, of course, be inferred from the fact that vehicle size, weight, and travel are the variables which influence the incremental solution. For combination vehicles, approximately 40 percent of responsibility was derived from the pavement analysis. Table 3 and Figure 1 show the composition of the responsibility assigned to the several vehicle classes in Kansas.

Passenger cars and small trucks in the two-axle four-tire class accounted for 88 percent of the total vehicle-miles of travel and were allocated 78 percent of the total highway user responsibility by the incremental solution in Kansas. The distribution of

TABLE 3
COMPOSITION OF USER RESPONSIBILITY BY VEHICLE CLASS INCREMENTAL
SOLUTION, KANSAS

Vehicle Class	Derivation of User Responsibility (%)				Total
	Pavement ¹	Bridges	Grading & Drainage	Misc.	
Passenger cars	12	8	11	69	100
Single-unit trucks and buses:					
2 axles - 4 tires	12	8	11	69	100
2 axles - 6 tires	24	15	13	48	100
3 axles	29	30	10	31	100
Combination trucks:					
3 axles	39	21	10	30	100
4 axles	40	28	8	24	100
5 or more axles	39	33	7	21	100
Total	17	11	11	61	100

¹Based on AASHO Road Test results.

total costs assigned to each of the four incremental cost categories is shown in Table 4. Figure 2 shows total cost responsibility and travel by vehicle class.

Tables 3 and 4 show the relatively great influence that the Road Test equations have in the allocations to heavier types of vehicles. The influences of vehicle type and axle configuration is particularly apparent in Table 2 in the percentage of responsibility derived from structure costs and pavement costs. Both of these cost categories depend on travel and operating weight for the allocation. For the two heavier classes of single-unit trucks, the increase in average operating weight is apparent in the twofold increase

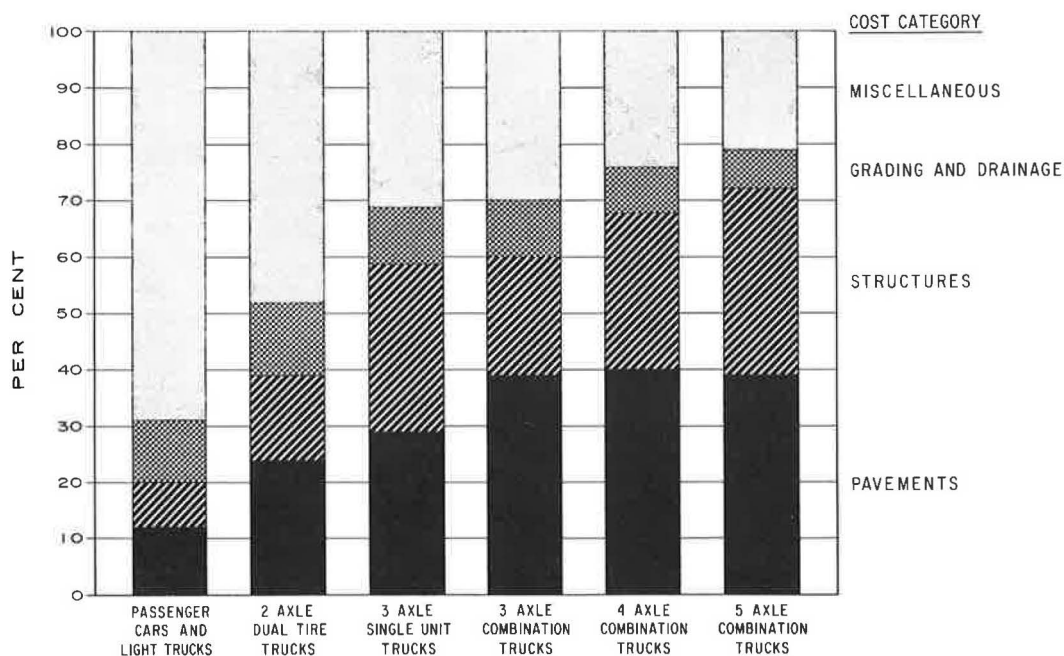


Figure 1. Composition of user cost responsibility, Kansas.

TABLE 4
TOTAL RESPONSIBILITY OF ALL VEHICLES BY CLASS INCREMENTAL
SOLUTION, KANSAS

Vehicle Class	Cost Categories (%)				All Costs
	Pavement ¹	Bridges	Grading & Drainage	Misc. ²	
Passenger cars	49.7	47.2	70.8	77.8	68.8
Single-unit trucks and buses:					
2 axles - 4 tires	6.7	6.6	9.6	10.4	9.2
2 axles - 6 tires	10.7	10.0	8.8	6.0	7.6
3 axles	1.7	2.6	0.9	0.5	1.0
Combination trucks:					
3 axles	6.1	4.9	2.4	1.3	2.6
4 axles	13.8	14.6	4.3	2.3	5.9
5 or more axles	11.3	14.1	3.2	1.7	4.9
Total	100.0	100.0	100.0	100.0	100.0

¹Based on AASHO Road Test results.

²Distribution identical to distribution of total travel by vehicle type.

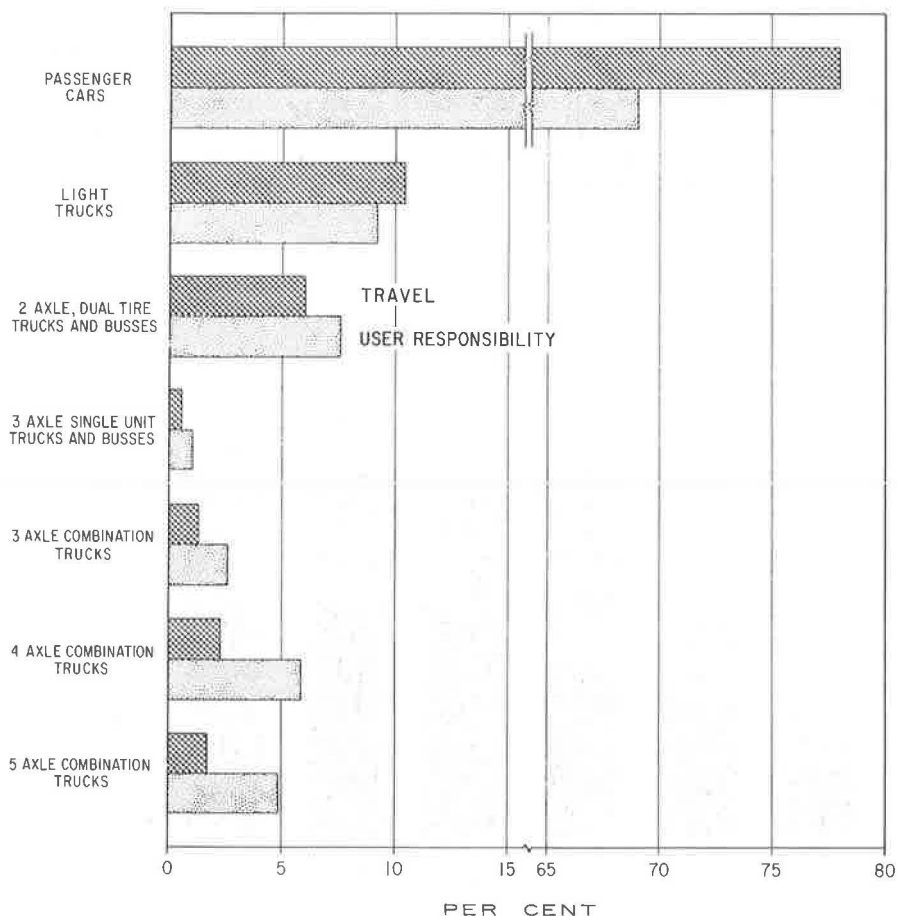


Figure 2. Total user responsibility and travel, Kansas.

in proportion of responsibility in the bridge category. For the same vehicles, pavement responsibility is increased by a factor of 1.2, reflecting the low equivalent single-axle load that replaces the total load on the tandem axles of the three-axle single-unit trucks. The relatively uniform proportion of responsibility for pavements of all combination trucks reflects this same influence. South Dakota results conform to these characteristics, but the effects are less apparent because of sharp fluctuations in reported travel for different vehicle types and weights.

USE OF INCREMENTAL SOLUTION IN FORMULATING RECOMMENDATIONS

Because of the sound basis in logic of the incremental method and because of its inherent ability to reflect the effect of vehicle type on highway costs, the incremental solution strongly influences decisions on user taxation recommendations. Other factors influencing realistic recommendations include allocations by the cost-function, vehicle-mile, and ton-mile methods; the highway user tax structure of the State; the current rates of taxation in the State; and the rates and bases for taxation in other States, particularly those in the same general region. Ideally, the recommended user taxes should

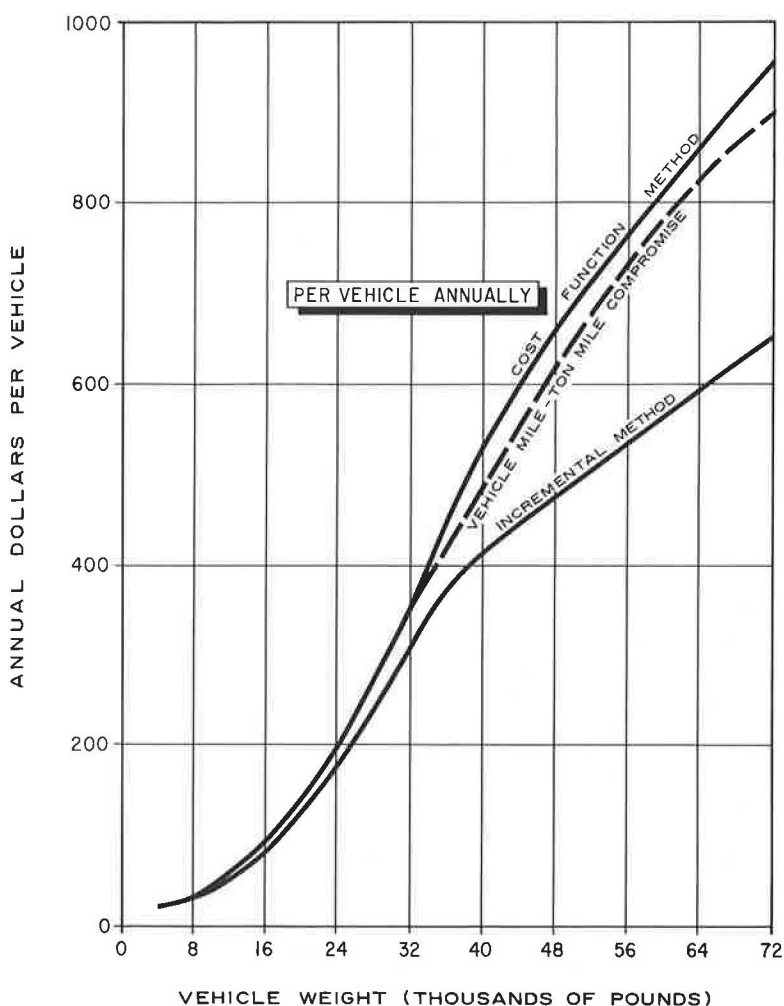


Figure 3. Average cost responsibility per vehicle annually, Kansas.

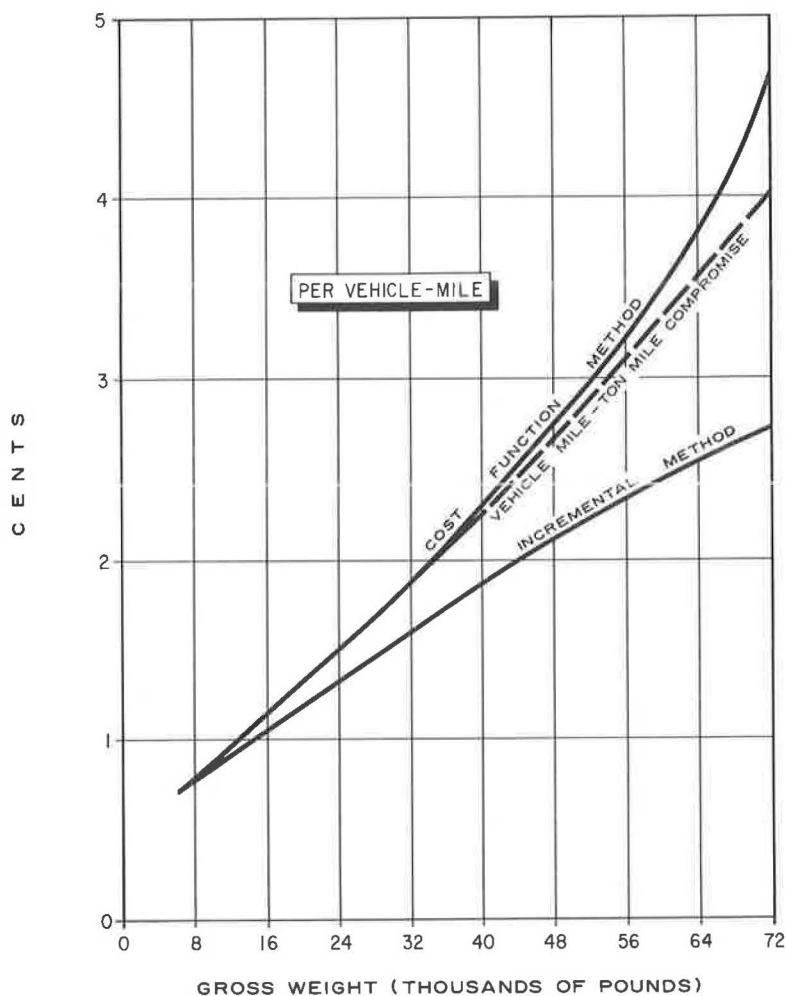


Figure 4. Average cost responsibility per vehicle-mile, Kansas.

provide the needed revenues, assess these revenues in relation to responsibility, and follow a tenable political course. Responsibility varies with type and weight groups of vehicles and with variations of use within the group, making a balance between annual taxes and use-related taxes necessary for equity.

The cost-function allocation and the average of the vehicle-mile and ton-mile allocations were quite similar and the general relationship to the incremental solution was the same in each State. The incremental solution allocated relatively greater responsibility to passenger cars, about the same responsibility to light trucks, and relatively lesser responsibility to heavy trucks with the proportional difference increasing as the weight of the vehicles increased. Figures 3, 4, and 5 show the relationship between the cost function and incremental allocations by gross vehicle weight without regard to type. These curves are for trucks and buses only, and show the average annual responsibility per vehicle and the average responsibility per vehicle-mile and per ton-mile over the period from 1963 to 1982 (2, 3). Table 5 gives the same data by vehicle type and includes the responsibility for passenger cars.

Solutions of allocation assigned total responsibility to each class of vehicles. These totals were reduced to per vehicle, per vehicle-mile, and per ton-mile to facilitate appraisal and presentation. The per-vehicle-mile and per-ton-mile responsibilities

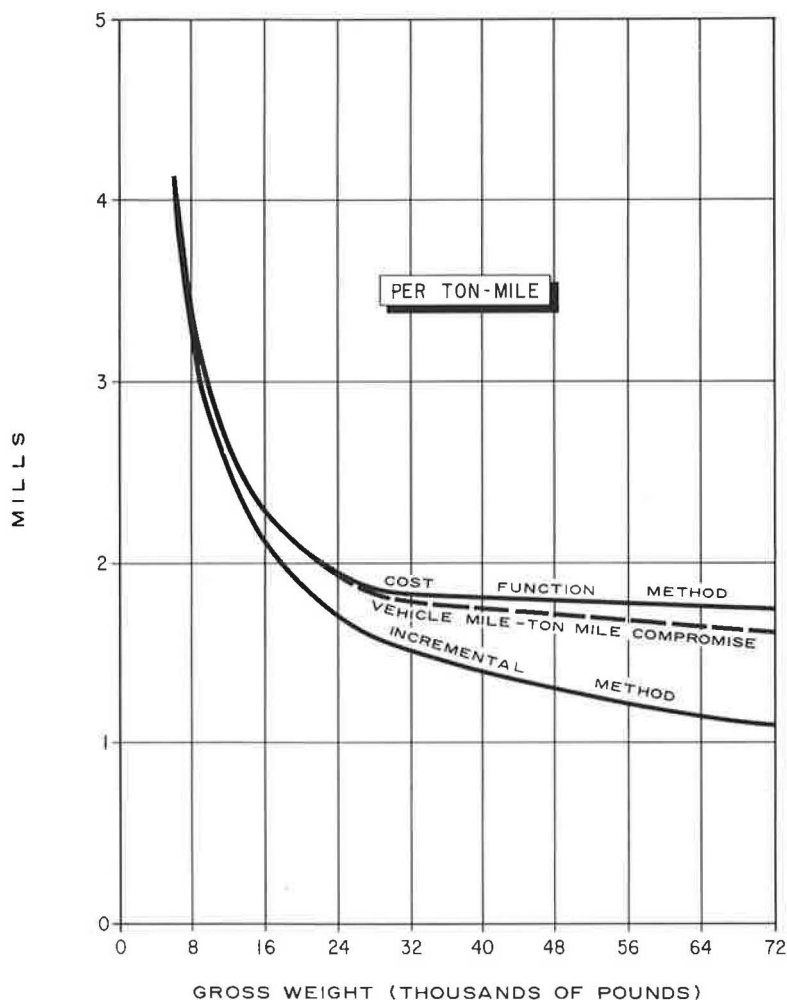


Figure 5. Average cost responsibility per ton-mile, Kansas.

TABLE 5
AVERAGE COST RESPONSIBILITY BY CLASS OF VEHICLE, KANSAS

Vehicle Type	Annual Cost (\$)					
	Per Vehicle		Per Vehicle-Mile		Per Ton-Mile	
	Incre- mental	Cost Function	Incre- mental	Cost Function	Incre- mental	Cost Function
Passenger cars	86	77	0.008	0.007	0.0042	0.0037
Single-unit trucks and buses:						
2 axle - 4 tire	53	54	0.008	0.008	0.0032	0.0032
2 axle - 6 tire	105	118	0.011	0.013	0.0019	0.0021
3 axle	310	401	0.017	0.022	0.0014	0.0018
Combinations:						
3 axle	437	546	0.019	0.024	0.0014	0.0018
4 axle	661	963	0.023	0.034	0.0012	0.0018
5 axle or more	547	888	0.026	0.043	0.0011	0.0018

were particularly useful in recognizing trends when average travel and average operating weights varied erratically.

SUMMARY

The AASHO Road Test has provided significant progress in the evaluation of cost responsibility for pavements. It is of particular value in determining relative influence of vehicle type and axle configuration on costs of the pavement structure. However, pavement costs represent a comparatively small part of the total cost responsibility which is normally assigned to motor vehicle users. The magnitude of this portion and the handling of other aspects of the incremental solution are dependent on subjective decisions. Also, there are other analyses and comparisons which must influence the judgment of engineers, administrators, and legislators in proposing and enacting tax rates and tax structures.

The equations derived from the Road Test pavement experiment provide a rigorous though somewhat cumbersome method of allocating pavement responsibility. The quality of the solution is, of course, related to the quality of traffic, pavement design, and cost data to a very large degree and to a lesser degree on method selected to evaluate mixed traffic. In the studies that provided the background for this paper, both data and method were considered entirely adequate for a valid solution.

Results of the incremental analysis, when compared with other allocations, indicate a greater responsibility for passenger cars and proportionally increasing lower responsibility for trucks as weight increases. The tendency for the incremental responsibility to diverge from the responsibility by other methods as vehicle size and weight increases is attributed to the influence of vehicle type and axle configuration in the bridge and pavement categories of the incremental solution.

REFERENCES

1. "The AASHO Road Test: History and Description of Project." HRB Special Report 61A (1961).
2. "Highway Finance in South Dakota." Wilbur Smith and Assoc., New Haven, Conn. (Nov. 1962).
3. "Fiscal Aspects of Kansas Highway Programs." Wilbur Smith and Assoc., New Haven, Conn. (Nov. 1962).
4. "Money for Miles in Mississippi." University of Mississippi, School of Business and Government (Dec. 1961).
5. "Financing Missouri's Road Needs, An Analysis of Revenues, Expenditures and Methods of Financing Missouri Road Needs to 1980." University of Missouri, School of Business and Public Administration (Dec. 1960).
6. "Serving Ohio's Traffic: Looking Ahead to 1980." Wilbur Smith and Assoc., New Haven, Conn. (Nov. 1962).
7. "Kansas Highway Needs: An Engineering Appraisal." Roy Jorgensen and Assoc., Washington, D. C. (1962).
8. "South Dakota Highway Needs: An Engineering Appraisal." Roy Jorgensen and Assoc., Washington, D. C. (1962).
9. "First Progress Report of the Highway Cost Allocation Study." House Document 106, 85th Congress, 1st Session, Washington, D. C. (1957).
10. "Final Report of the Highway Cost Allocation Study." House Document 54, 87th Congress, 1st Session, Washington, D. C. (1961).
11. "Highway Cost Allocation Study, Supplement to Part IV-B: A Preliminary Allocation of Cost Responsibility by the Incremental Method." U. S. Department of Commerce, Bureau of Public Roads (1961).
12. "The AASHO Road Test, Report 5: Pavement Research." HRB Special Report 61E (1962).
13. Duzan, H. C., Oehmann, J. C., and Davis, J. M., "Use of Road Test Equations in Pavement Cost Allocation." HRB Special Report 73, 393-398 (1962).
14. Scrivner, F. H., and Duzan, H. C., "Application of AASHO Road Test Equations to Mixed Traffic." HRB Special Report 73, 387-392 (1962).