Concepts of Cost Function and Incremental Solutions of Vehicle-Tax-Allocation Problem

E.V. KILEY, Director, Department of Research
American Trucking Associations, Inc.

● A DISCUSSION of the incremental solution of the motor-vehicle-tax-allocation problem begins in the favorable atmosphere of its being generally recognized as the soundest approach to the problem.

This recognition of the theoretical soundness of the incremental approach stems from its inherent acknowledgment of the fundamental fact that highway-user taxes levied on individual vehicles, or groups of vehicles, should bear as close a relationship as possible to the actual costs these vehicles bring into existence.

Proper application of this principle must, of course, be preceded by acceptance of the collateral principle that the purpose of highway-user taxation is to recover from the highway users their fairly assigned share of highway costs.

In states where highway-tax and highway-cost studies have been undertaken, it has been readily admitted that the incremental method represents the soundest approach. However, statements to this effect are often qualified by the comment that the incremental solution requires the accumulation of a great deal of material that is not available, with the time factor cited as an insurmountable obstacle.

These may be valid reasons for the inability to apply the incremental solution. Being the more complex of suggested approaches, it represents considerably more work and extensive research.

It is somewhat ironical, however, that these acknowledgments of the soundness and desirability of the incremental approach are then followed by the application of a method that is completely opposed to the incremental, both in principle and in purpose.

In many states where gross ton-mile analyses have been made, it has been only after a frank admission that the incremental is the soundest and the best and should be applied if at all feasible. Thus, they begin their studies by contradicting in principle the method they attempt to apply and persist in making ton-mile analyses and, on the basis of their findings, recommend severe adjustments in the level of truck taxes.

The ton-mile approach contains the basic fallacy of ignoring completely the fundamental characteristics of highway costs. There are many different elements affecting the cost of building and maintaining roads and streets. Modern highway construction and maintainance is a complex undertaking. There are many different things to be considered, and each has an important effect on the ultimate costs of highways.

For example, such important elements as rain, snow, and excessive temperatures all have harmful effects on highway surfaces, unless built to withstand their destructive action. In addition, many costs of maintainance and administration are influenced solely by the volume of vehicular traffic, irrespective of vehicle size or weight.

Vehicle weight is a factor in determining the level of highway costs, but it is only one factor out of many. To use one measure of use, such as ton-miles, is to ignore the other factors and, therefore, to exaggerate beyond equitable proportion the proper responsibility of some vehicle groups.

Nevertheless, this invalid procedure was followed in the ton-mile analyses that were made. The sound principles behind the incremental method were completely and rudely discarded. The true relationship between highway-tax responsibility and highway costs was distorted beyond reason.

The error of the ton-mile approach becomes readily apparent when highway costs are analyzed on a more-scientific basis. Such a basis is provided in the incremental method; but the ton-mile studies were being made in those states where the incremental method was not considered, because of the extensive research that would be required.

Failure to consider the incremental approach because of technical and research difficulties was understandable. However, the abandonment of accepted principles is inexcusable.

The trucking industry found itself facing the brunt of the assult from the ton-

mile analyses. Inevitably, they resulted in charges that truck taxes were too low and recommended severe adjustments, including the imposition of third-structure taxes.

In the face of this assult, and to bring the highway cost-tax relationship into proper focus, the industry developed and applied what has been called the cost-function method of highway-tax analysis.

The cost-function method analyzes all elements of highway construction, maintainance, and administration and segregates them into groups according to the factors that are predominant in bringing the costs into existence.

The first group of costs contains those items which are not affected by either miles of travel or weight of vehicles, such as beautification, landscaping, and similar roadway improvements. In the states in which studies have been made, these costs have been found to range from 10 percent to 14 percent of the total cost.

The second group of costs are those which are affected by mileage, or volume of traffic, but not by variation in vehicle size or weight. To a large extent these are basic highway costs and cover such items as traffic control, right-of-way expense, clearing, grading, etc. These costs, classified as nonweight-use costs, are assigned to the various vehicle groups on the basis of miles operated and have been found to comprise from 35 percent to 43 percent of total costs.

The third group, called weight-use costs, contains those items affected both by mileage operated and weight of vehicles. They are the major construction as well as surface-maintenance costs. They have been considered to be allocable to the various vehicle groups on the basis of ton-miles operated and have been found to comprise 45 to 50 percent of total costs.

The use of ton-miles, even to allocate those costs where vehicle weight may be admitted as a factor, still tends to overstate the responsibility of the larger vehicles. One reason for this is the use of gross weight in determining responsibility for highway-surface costs, whereas accepted engineering principles, as set forth in the incremental approach, tell us that axle wieght, rather than gross weight, is the controlling element in determining pavement stresses generated by larger and heavier vehicles. Gross vehicle weight may be a factor in determining the bearing stress of structures, but it gives way to axle weight as a factor in pavement design.

In those states where the cost-function analysis has been used, it has clearly shown gross inequities in the ton-mile method. The mere fact that the ton-mile method automatically assumes that gross weight is a factor in all elements of highway costs, whereas analysis develops that fewer than 50 percent of highway costs may conceivably fall in the weight category, is sufficient to condemn the ton-mile approach as a dangerous expedient.

An additional element that tends to overstate the responsibility of the heavier vehicles is the fact that contained in the weight-use category is the entire cost of surface construction. This means that a great many of the truly basic road costs are still assigned on the basis of vehicle weight, although a significant portion of them would remain even in the absence of the larger vehicles.

Despite these deficiencies, the cost-function approach has earned deserved recognition as a valid approach to the tax-allocation problem. This has come about not only because of its exposé of the weaknesses in the ton-mile method but because it seeks to inject the element of scientific analysis in the highway-tax field. It accomplishes this through detailed investigation and segregation of highway costs and an effort to bring into focus the important relationship between highway costs and the vehicles that use our roads and bring these costs into existence.

It is in this important respect that the cost-function approach tends in the direction of the incremental method. The latter is much preferred and should be used in those states where there is a sufficient resevoir of data and adequate background of acceptable information that makes a complete incremental study possible.

Actually, the cost-function method is also dependent upon extensive information on all elements of highway cost. It requires detailed segregations of all items of construction, maintainance, and administration. As data on these expenditures, where available, must be taken from the records that reflect different methods of accounting, the same segregation of items is not found in every state. However, despite these differences, the var-

iation in the assignment of items among the three classes has not shown unusual variation in the states where studies have been made.

The cost-function study that was completed in Virginia in 1952 was coupled with an incremental study that was part of the same report. This report was submitted to a study commission on behalf of the Virginia Highway Users' Conference. An incremental study was possible in Virginia, because of the method used by the state in planning and constructing its road system. The state has in effect two road systems, which, for the sake of brevity, may accurately be referred to as its truck-road system and its non truck-road system. The latter is designed, and accordingly paid for, as a road system to carry normal, basic vehicular traffic. Truck traffic is not considered a factor in the design of these roads.

The remaining roads in the state's system are its truck, or general-purpose, roads, and these are designed with truck traffic in mind. Sufficient data on the design and costs of both road systems were available to enable an incremental study to be made. The difference between the cost of the nontruck road was considered to be the increment, or additional cost, to be assigned to truck traffic. The remaining costs were considered the basic costs, to be distributed to all vehicles on the basis of mileage operated.

It is not necessary to go into detail as to the findings in the Virginia study. However, it is significant to note that the findings as to tax responsibility in the incremental study and in the cost-function study were remarkably similar in many respects. Both found that the prevailing tax system was generally fair and equitable.

The Virginia incremental study did not depend upon the acceptance of engineering principles or procedures nor upon agreement as to what constituted the basic road and what its costs might be. By actual practice the state was incurring actual expenditures for roads that were being built. The incremental costs lay in the cost records of the state and not in seeking general agreement as to what might or might not be built if there were no heavy vehicles on the road.

In contrast to the type of incremental study that was possible in Virginia are studies that must look for their validity in the acceptance of certain suppositions and hypotheses. In these cases there is no background of experience as to what constitutes the increments of costs as proven by practice. The study must set forth its assumptions and draw its conclusions based on these assumptions.

An illustration of such as assumption and its extreme importance is the basic road concept that is inherent in the incremental approach. The basic highway is the type of road that would be built if all motor vehicles were passenger cars and light trucks. These vehicles are classified as the basic vehicles.

Such a situation would mean that highways would not have to be built to carry the traffic of heavier vehicles, and engineers would not have to design weight-carrying capacities in the road system.

However, such a road would have to be designed to carry safely and expeditiously the large volume of passenger-car traffic, as well as the greatly increased volume of light truck traffic that would be required to take the place of the larger vehicles.

In addition, the basic road would have to be designed to overcome the destructive action of the elements, as mentioned earlier in the discussion of the ton-mile method. Engineers long have recognized that a good road's greatest enemy is the weather. Thus, although engineers may not have to design weight-carrying capacities in the basic road, they must continue to engineer for the elements.

Admittedly, the determination of the characteristics of the basic highway, and the resultant costs, is the most-difficult step in applying the incremental method. There is a tendency in some areas to treat the basic highway concept in a completely academic fashion and to forget that it must be a road that actually would be built in the absence of certain classes of traffic under prevailing conditions and not a road that might be built or possibly could be built.

The importance of the basic highway concept can be illustrated through reference to an incremental study recently completed in Minnesota. The Minnesota study selected the lowest type of highway design in each road system as the basic road, the one that would be built if there were no heavy vehicles.

All increments of cost were computed from this basic highway. Thus, the accept-

ability of the study's findings must rest primarily on the validity of the assumption that the state would design all roads in accordance with the standards of the 4,000-lb. -axle-load section, regardless of the volume of traffic the road would be called upon to carry. Such an assumption ignores the many important factors other than weight which influence highway design and highway costs.

In its publication "A Policy on Highway Types" (Geometric Design) the American Association of State Highway Officials states:

> Highways may be grouped in various types, th e highways in each group differing from those of other groups in broad physical characteristics and in facilities for accomodatıng traffic. The phase of traffic which has the greatest effect on general highway design is density of traffic.
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> The type of any highway should be related to the following factors: (A) traffic density; (B) character of traffic; (C) assumed design speed; (D) weight of traffic.
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> These factors are indicated by the approved classification in the Policy of Highway Classification, except that weight carrying capacity is indicated only indirectly.
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> The choice of the general type of highway is influenced more by traffic density than by any other factor . . . .

Although these remakrs relate to the geometric design of highways, (width of lanes, number of lanes, degree of curvature and gradient, etc.) it is also true that vehicle weight is not the sole factor in the determination of structural design. Structrual design is in reference to such items as pavement or surface thickness, bridges and structures, and preparation of subgrade.

It is true that vehicle weight is more of a factor in structural design than geometric design, but the extent to which ıt is a factor in structural design is also a matter of considerable conjecture. There are other equally important factors which must be considered in designing pavement thickness and subgrade characteristics. Among these are: traffic density, clımatic conditions, soil types, and frequency of heavy axle loads.

It is interesting to note the appearance of traffic density as an important factor in both design standards. It is also interesting to reflect on the fact that, while we have been conducting studies and attempting to reach conclusions as to the effect of climate, subsoil, and axle loadings on highway surfaces, there seems to be little available on the precise effect of traffic densıty on pavement thickness.

The importance of climatic conditions on highway design was emphasızed by Thomas H. MacDonald, then commissioner of the U. S. Bureau of Public Roads, in his testimony several years ago before the Interstate Commerce Commission in Docket 23,400. Commissioner MacDonald stated:

> We would not build roads much less than 7 inches at the edge and 6 inches in the center, no matter what kind of loads we were going to carry.
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> If we built thinner surfaces they would curl up like tissue paper in the rays of the sun. They would warp; the frost heave would destroy them.
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> So we have a certain minimum thickness of roads that is necessary to build if there were nothing heavier than ordinary passenger cars and farm trucks to use the road, and the whole question of the heavier buses and heavier trucks therefore begins with a certain minimum thickness of road which is necessary regardless of whether they exist or not .

The importance of the basic road design cannot be overemphasized. In the Ohio incremental study the basic road was stated to be the equivalent of a 4-inch cement-concrete surface. This is an interesting specification. It is interesting not only from the standpoint of Commissioner MacDonald's statement but because, in the City of Columbus, a sidewalk must be 5 inches thick; where a driveway crosses the sidewalk, it must be at least 6 inches thick.

Recently at Metropolitan Beach, Macomb County, Michigan, bids were sought for the construction of a roller-skating rink. In the public advertisement setting forth the construction standards for the skating rink, it was specified that the surface would con-

sist of a 6-inch concrete slab. This requirement, together with the sidewalk requirement in Columbus, supports the concept that there is a minimum pavement thickness that must be designed, regardless of the load that may be imposed.

It is not suggested that sidewalk or skating-rink specifications be used as positive criteria for the design of highway surfaces. However, the existence of these specifications does illustrate the large area of controversy that surrounds the basic highway concept and its translation into actual costs.

The importance of traffic density as a factor in highway design seems to be submerged in some incremental studies that have been made. There seems to be considerable confusion in evaluating the dual effect of traffic density and the frequency of heavy axle loads.

Certainly we need to know a great deal more about the importance of axle load frequencies, but at the same time, we should know more about the effect of traffic density as a factor in itself. We know from actual traffic-volume studies that the high frequency of heavy axle loads is almost always found on roads of the highest traffic density. Despite this important fact, there is a tendency in some quarters to assign the additional highway costs solely to the axle-load frequencies; ignoring completely the important effect of traffic density. On many of these roads the elemination of the heavier axle loads would have no appreciable effect on road design. The presence of a high density of traffic would demand a facility of equal cost.

In addition to the selection of the basic highway and the determination of its costs, proper application of the incremental analysis calls for the assignment of certain highway costs to each vehicle group on the basis of miles operated. The costs to be assigned on this basis are the nonweight costs—the costs that are not affected by differences in vehicle size and weight.

Ordinarily this would seem to present no problem. However, in the case of vehicle combinations (tractor semitrailers and truck trailers) it has been advanced by some that separate mileage responsibilities should be computed for each unit. Such a procedure was followed in Ohio and Minnesota. Under this procedure, a tractor-semitrailer combination traveling 40,000 miles per year is given a mileage responsibility of 80,000 miles; 40,000 for power unit and 40,000 for the semitrailer. This means that a tractor-semitrailer combination with a total of three axles is charged with twice as much mileage responsibility as a three-axle truck of the same gross weight.

This is a procedure that is contrary to all principles of highway-tax analysis. The semitrailer, or cargo unit, is not a revenue-producing vehicle. It has no motive power and is incapable of producing mileage without the power unit, with which it forms an integral unit and becomes one vehicle. A double assessment of tax responsibility against these vehicles represents a penalty on vehicle combinations and places a premium on the efficiency that is gained through the use of articulated units.

The question of vehicle-combination mileage is one of the controversies surrounding the techniques involved in application of the incremental. There are others, including the use of axle mileage as a common denominator for the division of costs, that are not within the weight category.

However, the basic road—its structural and geometric design standards, its actual costs, and the type of traffic it could actually carry—remains the critical point in the incremental approach. It is in this area that the greatest amount of exploration is needed.