COST ALLOCATION REVISITED

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There has been general agreement that the costs of a highway improvement program should be borne partially by highway users and partially by the general public and property owners. To divide highway costs equitably has been one of the more difficult problems facing highway economists. In answer to this problem, a number of pragmatic solutions have been designed and each has been advocated as being reasonably equitable in its results. The purpose of this paper is to evaluate critically and briefly analyze some of the more commonly used solutions. This discussion is not intended to describe the methodology of the various solutions, except as such descriptions are germane to analyzing the basic ideas of the solution.

Two types of solution will be examined: those dealing with cost allocation between users and nonusers and those dealing with cost allocation among the various classes of users. (The term "nonusers" refers to those who benefit from highways not because they operate a motor vehicle on highways, but because they receive indirect benefits from the highway system. Thus, lower costs if fire and police protection, lower costs in distributing economic goods and services, and increased property values are examples of nonuser benefits. Nonusers may be thought of as consisting of two classes: the general public and property owners.)

COST ALLOCATION BETWEEN USERS AND NONUSERS

Basically, highway cost allocation solutions adhere to either the costs incurred for the benefit of the various beneficiaries, or on the benefits actually received by each of the various groups. Three of the most common solutions in state highway finance studies will be briefly considered: the relative-use solution, the earnings-credit solution, and the standard-cost solution. The relative-use solution is based largely on the benefits received theory; the other two are built on the costs incurred theory.

Relative-Use Solution

In this method, the traffic on a given road section is divided into three different types: land access, neighborhood, and through traffic. Sample studies are actually made to determine as accurately as possible the percentage distribution of each of these three types of traffic for each road system. The percentage distributions are then applied to the program disbursements to determine the dollar cost applicable to each type of travel on each road system. Through traffic is regarded as user responsibility, land access and neighborhood traffic are the responsibility of nonusers.

Theoretical Implications.—The relative-use method rests on a generally accepted theoretical basis. There is, however, some disagreement as to what constitutes an appropriate measure of relative use. In the Federal Highway Cost Allocation Study, (1) (hereafter referred to as the Section 210 report) for example, vehicle-miles were selected as an appropriate determinant of use. Other authorities have suggested that ton-miles might be a better measure of relative use. Still another authority (2) has suggested that the ton-mile method might be appropriate if a modification were added to provide for the fact that different amounts of highway space are occupied by different vehicles.

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The relative-use solution gives some insight into the deriving of taxes with which to meet the user and nonuser responsibility. This is an advantage not possessed by most cost allocation methods.

There is, however, one theoretical weakness in the relative-use method. After the traffic is divided into the three sections, an attempt is made to allocate highway cost to property owners, the community, and motor vehicle users. All of the traffic, however, is motor vehicle traffic and motor vehicle user taxes are generated by all three classes of traffic. To allocate some of the burden to nonusers on the basis of road user earnings is not theoretically sound (3). In an attempt to deal with this problem the earnings-credit solution was developed, which attempts to make allowance for the user earnings generated on each system.

Other problems posed in this solution are problems of application and measurement. Considerable attention must be given to these problems, as they pose further limitations on the usefulness of the relative-use method.

Problems of Application.—The relative-use solution requires rather extensive primary data. Such data may come either from a survey taken for the purpose of finding data specifically for a relative-use study, or from data adapted from national averages. There are, however, some dangers involved in attempting any type of relative-use solution which uses national averages.

The main controversy in the relative-use method concerns the definitions of the access and neighborhood component of a trip, especially in urban areas. In the Section 210 report, for urban areas, a standardized urban access distance had to be adopted.

The Section 210 report adopted two procedures for defining the neighborhood component. Both of these procedures seem to have validity. In procedure A the neighborhood component radius was related to population density. Procedure B related this radius to a fixed number of trip units per day. Procedure B resulted in a reduction in the size of the neighborhood component of the trip in urban areas, and an increase in the size of the neighborhood component on rural areas. The resulting changes in allocation were significant but not of an extraordinary magnitude. In the final allocation, the results of the two procedures were averaged to obtain user and nonuser tax responsibility.

A state employing the relative-use method will be required to make some kind of judgment as to the appropriate definition of a neighborhood component. It is possible, then, that an inappropriate definition of a neighborhood component may result in a distorted picture of tax responsibility. It does not seem possible to adopt a rigid definition that can be applied in all instances. The definitions finally chosen for the neighborhood component must be the result of intensive investigation of the situation and composition of a given area.

Because there have been relatively few attempts at the relative-use method, it is not possible to make significant comparisons of the results of this method with those of other methods. Although the solution is widely accepted, it possesses a serious shortcoming in that it attempts to allocate nonuser responsibility on the basis of traffic which generates user revenue. In spite of the theoretical difficulty and the difficulties of application, a more extensive application of the theory would probably be desirable before making a final judgment on its merits.

Standard-Cost Solution

The standard-cost method is based on the cost of a standard or representative road. Such a cost is typically translated into a cost per ton-mile of travel on the standard road, and then applied to the total ton mileage for all roads and streets to determine the total user share. The deficiency in revenue necessary to pay the entire cost of a highway improvement program is then assumed to be the responsibility of nonusers. This method was employed in a study for the Ohio Highway Program Commission in 1951 (4).

The costs of a highway improvement program are in the nature of joint costs; that is, the costs are incurred for simultaneous benefits to several groups. In attempting to allocate joint costs among many groups, it is common practice to start with the group that represents either the largest segment of cost or whose cost is the most easily determined. The remaining cost is treated as residual cost, the burden of which falls on the remaining groups. In the case of highways, motor traffic "enjoys a highly specialized service, associated with definite types of facilities provided at definite costs." (4)

In attempting to determine the cost of providing highway facilities for motor vehicle traffic, it must be realized that there are highway facilities which are provided not only for motor vehicle traffic, but which also bring substantial benefits to nonuser groups. For this reason, it is necessary to develop the concept of a reasonable cost which may be properly allocated to motor vehicle traffic.

To obtain a reasonable cost requires the selection of some portion or portions of the highway system which can be assumed to represent reasonable conditions. The type of highway facility, the volume of traffic, and the composition of the traffic must be reasonable; if such conditions are reasonable, the cost of highway facilities on these portions of road will also be reasonable. In the Ohio study, the highest type state rural systems, and the middle type state rural systems were selected as roads possessing the characterictics regarded as reasonable. They operate throughout most of the year at somewhere near capacity, and they carry traffic which represents, presumably, every kind of motor vehicle and in approximately the proportions which prevail on a statewide basis. It is admitted in this study that cost under these conditions will not be precise, but it is close enough to a reasonable level that it may serve as a basis for the allocation.

Unit of Measurement.—In the Ohio study, ton-miles were used as an appropriate measure of value. This measure is not completely satisfactory as there are some elements of cost which it does not reflect. The author of the Ohio study, however, believes ton-miles reflect the major elements of cost: weight and distance. Much of the criticism of the ton-mile is based on the assumption that the ton mile defines the "energy absorbed by transportation."

The concept of the ton-mile as a measure of value or benefits is probably not adequate:

> It is asserted that the product, weight times distance, is a measure of value of use or value of service. . . . It is sufficient to point out that no affirmative proof can be offered that the product, weight times distance, is a measure of such value. . . . We can find no reason to say that, for these various types and sizes of vehicles, the value received from the use of types highway is proportional to their weight. . . . Value of service must be measured in fiscal, not in physical, terms. (5)

The authors of the Ohio study contend, however, that the use of the ton-mile in a standard-cost solution is not intended to be a measure of benefit, but is intended to be a measure of cost. For this reason, they believe that many of the criticisms levied against the ton-mile are not applicable when the ton-mile is used for this purpose.

Certain other measures, such as vehicle-miles, energy input, and time-space, have been devised from time to time. Although the ton-mile has some shortcomings, it may be the best existing measure of transportation costs for this solution. It would be desirable to develop some kind of statistical unit that would give proper weight to all the different elements involved in highway costs.

Critique.—The standard-cost solution has one serious shortcoming which cannot be readily overcome. Applying the solution will result in a user responsibility that depends on the proportion of travel and the condition of nonstandard roads at a given instant in time. This may result in a serious distortion of appropriate user responsibility. An example will make this clear. Suppose that in a given state there are three classifications of state primary systems, and these systems are called A, B, and C. Type A represents the highest type state primary roads. This selection is presumably based on reasonable conditions; type A is not included because it represents the highest type of primary system. Suppose that the necessary disbursements for types B and C are relatively low. It follows that the cost per ton-mile will be low and user responsibility will be relatively low. But suppose that the type A system requires very high program disbursements. A subsidy will occur in that the nonuser groups will be paying a relatively high burden, and will be subsidizing those users who use the type A system heavily. This can be further complicated by considering urban vs rural roads; it is easy to conceive that all kinds of inequities are possible depending on the relative needs of a given system at a given time. This weakness of the theory is not merely a weakness involved in making arbitrary decisions, but it bases the whole theory on a premise that is not entirely acceptable.

Another difficulty is that there is no criterion on which to select a representative road. Hence, confidence in the results of the solution is further undermined.

When the nonusers' share is determined, there is no criterion by which this share may be judged. Because it is treated as a residual, the appropriateness of the nonuser share depends on the appropriateness of the user share, which again falls back on the difficulties previously enumerated.

Another common criticism of the standard-cost approach is that it places a heavy burden on users, especially truckers. This arises from the use of the ton-mile as the unit of transportation. The ton-mile does not deal with vehicle size or the other use characteristics that might be helpful in allocating highway costs.

It is not possible in this solution to make a separation between urban and rural systems. One of the serious problems in modern highway finance is that of the earnings on urban freeways compared with the cost of providing them. The standard-cost solution is of no avail in dealing with this complex problem.

Basically, the standard-cost solution is presumed to follow the cost incurred theory, but in reality it does not. The theory attempts to take the total program disbursements and decide which of these costs were incurred for the benefit of each group. The standard-cost solution, in basing the allocation on a standard road, does not really do this. Neither does the method rely on the benefits-received theory.

The development of the standard-cost theory seems to have been an attempt to deal with the idea that highway costs are in the nature of joint costs. The method recognizes the idea of joint costs and attempts to allocate such costs on some kind of reasonable basis. This recognition is probably the strongest point in the method. But the fact that it rests on shaky theoretical grounds, as discussed, causes the results obtained from applying this solution to be questionable.

Earnings-Credit Solution

The earnings-credit solution was developed by personnel of the Bureau of Public Roads in an effort to bring several important principles of highway finance into a single solution. This method, like the relative-use method, recognizes that there are three types of traffic: through traffic, neighborhood traffic, and land-access traffic. This solution recognizes that some of each type of traffic will be found on each highway, road, and street.

The earnings-credit approach establishes an upper and lower limit of user and nonuser responsibilities. The final result of the solution is an average between these limits. The basis of computing the upper user responsibility limit is the cost of providing through traffic service on all types of roads. This is called the "top drawer solution." The basis of computing the nonuser responsibility limit is the cost of providing the minimum facility for land access, the so-called "bottom drawer solution."

The cost per vehicle-mile on the highest type systems (Interstate, state primary, and urban freeway) is used as the standard in computing the cost of all road systems that should be allocated to the through travelers on these systems. In this way, the cost of through traffic is separated from that of community and land-access traffic on medium and lower type roads. The cost of all through traffic on these systems is then allocated to the users; the residual costs are allocated to the nonusers.

In computing the maximum nonuser share, the cost per mile on the lowest type road is established as a standard for separating local land-access traffic from through traffic on medium and higher type roads. The cost of the land-access traffic on all types of roads is then allocated to the nonuser; the residual cost is allocated to users.

In this way, two different answers result. A compromise is then made by arithmetically averaging the results of these two separate calculations. This compromise recognizes that there are some kinds of each traffic on each highway, road, and street. It compromises, basically, the two opposing hypotheses previously set forth (6). Ross says that ". . . this method adopts hypotheses with alone are untenable but which may be given mathematical interpretation and which may be compromised by precise computation producing a result that is believed to be logical and plausible" (7).

Philosophy.—Local road and street systems do not, and perhaps should not, generate sufficient road-user revenues for their own support. Basically, the earnings-credit solution is an attempt to modify the relative-use solution by making adequate allowances for the road-user tax earnings on each system.

In attempting to correct the inadequacies of the relative-use solution, certain compromises are made. The earnings-credit solution does not attempt to set forth a completely logical solution to the highway cost allocation problem, but rather to set forth a method by which several important concepts, none of which can stand completely alone, may be brought together.

This solution bases the allocation of relative tax responsibility on a precise calculation, which is a function of certain readily available data. Such data do not depend on judgment in their exercise. Therefore, it is felt that the earnings-credit solution is a practical and workable method by which tax burdens may be determined.

Nonetheless, it is true that judgments are made in establishing the procedures for the earnings-credit solution. The principles to be compromised, for example, are those that are judged to be the most appropriate for the purpose of allocating costs.

Basic Principles.—The top drawer solution uses cost per vehicle-mile to determine the user share, whereas the bottom drawer solution uses cost per mile to determine the nonuser share. It is true that urban highway construction has a higher cost per mile than rural highway construction. Nonetheless, the cost per vehicle-mile of providing urban roads is typically lower than the cost per vehicle-mile of providing rural roads. If highway costs were assigned only on the basis of vehicle-miles, the users of heavily traveled primary roads would subsidize the users of lightly traveled rural roads. If costs were entirely allocated on the basis of road mileage, the users of local roads would pay the same rate as the users of through routes and urban routes which are considerably more expensive. The earnings-credit solution compromises these principles by using cost per vehicle-mile in the top drawer solution and cost per road mile in the bottom drawer solution.

The same idea may be stated in a somewhat different way. On heavily traveled roads and streets, high levels of user revenues are generated per mile. Low revenues per mile are generated by local access roads and streets: "Either user taxes would have to be increased sufficiently to sustain the cost of highways on all systems, or owners of abutting property and local residents would be called upon to make up the difference between user generated revenues on low level systems and the total cost of these low level systems. The second alternative is chosen in the earnings credit." (8)

Therefore, in the earnings-credit solution, road-user tax earnings are credited to urban streets at a lower rate per vehicle-mile than to rural roads. This compromise seems inevitable because the cost per vehicle-mile is considerably lower on urban systems than on rural ones.

Fundamentally, the earnings-credit solution has assumed that the cost per mile of highways increases with the capacity of that highway. Furthermore, this increased cost is at a decreased rate with respect to increases in capacity. In reality, it is possible that these assumptions could be violated. If, for example, traffic did not keep pace with or was to exceed its capacity, for a single highway system, this assumption would not be met (8).

It should be pointed out that to say the cost per mile of highways increases with capacity is not the same thing as saying the cost per mile of highways increases with density. Capacity is presumably determined by an engineering study, and the capacity determines the cost to be allocated. On the other hand, the density of traffic determines the user tax earnings on a given system. A given capacity does not assure a given density. If capacity and density were precisely related, then the problem would be somewhat simplified. The attempt is to allocate highway costs, which are a function of the capacity of the highway. The basis on which this allocation is made is that of earnings, or benefits that bear a close relation to density. The differences between these two ideas pose a limitation to the results obtained in the earnings-credit solution.

Another major premise in the earnings-credit solution is that cost per vehicle-mile decreases as the density, or traffic volume, increases. It has been shown statistically that such a correlation exists (3). For this reason, motor vehicle users' responsibility will, in this solution vary directly with traffic volume.

State highway finance studies typically employ a "program disbursements" cost concept, such disbursements being determined by a needs study. These disbursements are determined so as to bring all highways, roads, and streets up to a given standard. Hence, the behavior of costs in relation to miles or vehicle-miles is partly a function of how various road systems have been maintained during a past period of time. Hence, in a given state, if more attention has been given to higher type systems than to lower ones—propertionally more than would reasonably be expected—then this may distort the relationship of cost per mile and cost per vehicle-mile in relation to traffic density.

Some Criticisms.—Many have criticized this method because it does not relate the costs of a system to the earnings on that system. Motor vehicle tax earnings are not generated at a uniform rate per vehicle-mile on all highway and street systems. There are several reasons why there may be wide variations in motor vehicle tax earnings. The type of road improvement may cause some variation in the amount of gasoline consumed. Also, differences in gasoline consumption between rural and urban areas are likely to occur. Congestion and other factors typically mean that fewer miles per gallon are obtained in urban driving than in rural driving.

Some roads have a relatively high percentage of heavy vehicles. These roads will generate tax earnings at a higher rate than will roads having a lower frequency of heavy vehicles. Thus, type and weight composition of traffic is apt to vary widely.

The characteristics of the whole motor vehicle tax structure in a given area is also likely to cause such differences. For example, if motor vehicle registration fees and carrier taxes are taken into the analysis of motor vehicle tax earnings, different types of vehicles may generate different types of tax earnings. No generalization is possible; each case must be treated separately.

Thus, the implicit assumption in the earnings-credit solution that motor vehicle tax earnings are generated at an equal rate on all systems may render the results inaccurate. It would be desirable to find a solution capable of dealing with these variations in a detailed manner. The extent of such distortion may be great, depending on the characteristics of a given state or area.

In using program costs for allocation, a distortion may result because of the fact that higher type highway improvements have longer average lives than do lower type improvements. Program costs may be translated into an annual cost basis, in which the average lives of the improvements on each system would be taken into account. Although a superior concept, this is not usually done as a practical matter since it poses a number of difficulties.

In the Section 210 report, however, a cost basis was used which did reckon with the different investment lives of different cost elements. For each road system, values were estimated for the investment life of right-of-way, grading, surfacing, and structures. The values used in this report were based on investment life studies in a number of different states. After this was done, annual capital costs were derived by multiplying the given investment item by the recovery factor that would provide for replacement of the item, at a given rate of interest, at the end of its investment life.

In the Section 210 report, calculations were made at various interest rates. It was felt that a rate of 2.5 percent probably simulated a normal condition, and was therefore more appropriate than higher or lower rates. Selection of the interest rate, of course, involved arbitrary decision. This is probably a better approach, however, than simply using program costs.

Conclusions.—The earnings-credit solution has the advantage of relatively easy data collection and of not relying on value judgments, and it is a solution which fits well into a future expenditures program for a state. It is not based on a rigorous theory, but is an attempt to provide a reasonable solution based on several good theories—of which none are good enough to stand alone. It may be said then, that the earnings-credit solution is grounded in two widely accepted principles:

1. That user tax allocations to the lower systems should not exceed the rate per vehicle-mile that can be used efficiently on the primary systems; and
2. That a nonuser component of tax support based primarily on the rate per mile at which access and other local services provided on the tertiary systems, should supply the remainder of the needed tax support. (1)

Even in its simplicity of application, there are a number of theoretical issues involved, some of which are rather complex, and there are bound to be some irregularities in data, which may pose at least a minor limitation. It does, however, achieve the two objectives listed above.

ALLOCATION OF USERS' SHARE AMONG CLASSES OF USERS AND TYPES OF VEHICLES

Once an equitable allocation of highway costs is made between users and nonusers, the next major problem is that of allocating the user share among different classes of users and types of vehicles. It is generally agreed that the operator of a large tractor-trailer truck should pay more user taxes than the operator of a passenger car. Such a truck not only uses the highways to a much larger extent, but because that truck uses the highways, higher engineering design standards are required—hence, higher costs. There are a number of different classes of users and types of vehicles, and taxes should be designed so that an equitable share of the burden is allocated to each class.

The two most commonly employed methods are the incremental solution and the gross ton-mile solution, both of which will be briefly analyzed.

Incremental Solution

By 1930 it had become obvious to many authorities that highway costs were related to the particular types of vehicles and the service which they demanded. The emphasis was on the fact that roads and streets were necessarily built to accommodate the demands of heavier vehicles (9). This is essentially the idea which underlies the incremental solution. The following is instructive in explaining the basic idea:

> The basic cost of constructing, improving, and maintaining a given highway shall be determined from a highway design for private passenger vehicles and other vehicles commensurate with their width. All vehicles using such highways should pay their proportionate share of that total as a tax base. The total additional cost of construction, improvements, and maintanence to make a road suitable for a type of vehicle requiring such additional costs should be shared by each vehicle of that type and each vehicle of greater size. Thus, each vehicle should share in the base cost plus all increments of cost up to and including the cost required by it. (10)

For example, a vehicle falling in the second increment of cost should pay only for the miles it operates at a gross weight which requires the second increment of pavement thickness. Empty weight would require only the first increment.

The incremental method has the advantage of attempting to determine tax responsibility for each type and weight of vehicle so that it bears the same, or nearly the same, relationship to the cost occasioned by that vehicle (11).

To accomplish these objectives, the incremental analysis attempts to determine the successive increments of cost which may be associated with different scales of sizes and weights of vehicles. In determining the required program disbursements, the most important factors are thickness of pavement, width of pavement, grading, necessary structures such as bridges, and maintenance (12).

Analysis.—Many authorities have suggested that the philosophy underlying the incremental approach guarantees the optimum competitive use of highway facilities. It is "sound and in accord with the economics of commerce and a free enterprise society . . . thus the competitive use of highway transport as a benefit to the general economy of the Nation will be fully realized." (13)

Others also believe that the incremental cost concept is sound in that it leads to neutrality among competitive forms of transportation, and therefore to an optimal efficiency of operation (14). To the extent that the incremental solution can be accurately preformed, this advantage is realized.

Highways require large fixed expenditures, and because they do, each class of user must necessarily pay the entire additional cost of any service provided for its use. In addition, each class of user should pay its appropriate share of the cost of the facilities provided for the joint use of all groups.

> The method also shows whether the use of the highway by any group increases or decreases the cost of the highways to other groups, for if any group is paying less than the increment of cost incurred in its behalf the other highway users have to pay additional charges on account of providing that group with the facilities it requires. On the other hand, each class of vehicles which pays more than the increment of cost incurred in its behalf reduces the cost of highways to all other groups. (15)

At the same time, there are a number of difficulties and shortcomings involved in the incremental approach. The determination of the cost requirements of the basic vehicle is fraught with speculation and hypothetical assumptions. No general agreement can be reached on this question, and thus with the same given data, widely differing solutions are possible depending on the definitions chosen. (In a study conducted in Montana, in 1957, for example, considerable attention was given to this question. The method proposed by the Montana investigators was subjected to comments and criticisms by various groups. These criticisms are rather extensive in nature, and in many places it is not possible to completely justify their action. The method used in the Montana study, although based on good reasons, can be subjected to valid criticism.)

To reduce the various factors which enter into highway design to a reliable formula poses difficulties. For example, some have contended that required pavement thickness varies as the square root of the wheel load. The formula does not have widespread acceptance, and yet it can be partially justified. Different highway costs involve a number of things. One report suggests that wheel loads, vehicle speed, and roughness of pavement are among the most important factors (9). The recent AASHO road tests, however, provide great insight into this type of problem—although they do not answer all aspects of the problem.

One category of costs deserves particular comment. The relationship of highway maintenance costs to vehicle size raises differences of opinions. In a study in Ohio, it was determined that 76 percent of maintenance costs were attributable to heavier vehicles and should be allocated incrementally. On the other hand, the study in Kentucky determined that maintenance costs were not related at all to vehicle size, and that all maintenance costs should be charged according to vehicle-miles. The latter viewpoint may be argued in that proportionally heavier vehicles do not occasion any greater maintenance expenditures on pavements and shoulders properly designed for them than would lighter vehicles on lighter pavements that could be used if no heavy vehicles needed to be accommodated (16). It is clear that some maintenance costs are not related to size (snow removal and brush cutting) for example. On the other hand, it may be true that pavement and shoulder surface maintenance do have some relation to the size of the vehicles using the highway. The important point is that there is no general agreement on this subject, as pointed out by the differences between the Ohio and Kentucky studies, and therefore another limitation is placed on the results obtained by an incremental solution.

Zettel points out that there is much uncertainty about measuring the specific requirements of various vehicle classes. He goes on to say that even with differential costs segregated, the big problem is the allocation of the larger amount of joint costs common to all vehicles:

> The extent to which special costs may have been incurred for the benefit of any particular class of vehicles is a question involving many variables. . . as in other joint-cost situations, this procedure recognizes that the costs, as such, cannot be traced specifically to any particular users or operations which are responsible for them, rather, it apportions the common costs on the basis of relative amounts of use. (17)

Zettel then proceeds to suggest that the gross ton-mile is the best measure of the amount of service received.

Considering the incremental method further, it is easy to see that vehicle characteristics other than weight and distance traveled have an impact on highway costs. Heavy vehicles, for example, take up more space, travel slower on grades, and perhaps contribute to accident hazards (18).

Traffic density is another important influence on highway design. Traffic composition, speed of vehicle, and many other factors are also important. At present there is no really satisfactory means of determining the importance of these items as they affect the costs of highways. To relate these items to vehicle size is dependent on a high degree of subjectivity.

Highway costs are also affected by magnitudes which are not charactersitics of vehicles. Differences in costs may be greater affected by such external variables as soil, weather conditions, and other natural characteristics (17).

Various incremental cost studies show a substantial lack of agreement as to the size of the incremental costs. Some studies show that only about 10 to 15 percent of the total highway costs should properly be incremental. Part of the difference stems from the fact that experience shows that highways in many cases may be built to approximately the same standards even if heavy trucks are barred from using them. In urban areas, the existence of many parkways and freeways attests to this fact. Thus, a question may be raised as to whether heavy vehicles should be charged expenses that may have been incurred even in their absence (12).

Passenger vehicles in some cases also contribute to cost increments. Speed, safety, convenience, and roadside development may be partly attributable to passenger vehicles. To successfully increment such costs, however, is probably impossible.

St. Clair has pointed to a possible danger that may be present when the final allocation has been made in the incremental solution:

> Since the final allocation takes the form of a lump-sum assignment of tax responsibility to the vehicles in each weight group, there is the . . . hazard that the required payment per vehicle in heavier weight groups will be so great as to discourage the use of such vehicles and thus decrease rather than increase the tax revenues derived from them. (19)

It is this limitation that has caused some incremental studies to be disregarded at the policy making level. St. Clair proceeds to point out that the results of the incremental, because of this possibility, must be tested by the use of other criteria of justice, ability to pay, and revenue productivity.

Throughout the discussion of the shortcomings of the theory, it is clear that many of the shortcomings hinge on the idea that considerable amounts of engineering judgment must be exercised. The use of judgment is commonly regarded as posing a limitation to any theory. But the judgment and experience of a highway engineer may be a better alternative than some theories which rely too much on arbitrary concepts that are adopted merely for their simplicity (5).

In performing an incremental solution, great care must be given to small details. A number of incremental solutions have been performed in a manner that undermines all of the validity associated with the theory. Although there are important fundamental questions raised in the method, it is on this basis that the results of an incremental solution may be trusted.

Conclusion.—The incremental solution rests on a firm theoretical basis. It contributes to tax equity and to an efficient utilization of highway facilities. The methodology that underlies it is technically sound. The difficulties are all ones of applying the solution; its nature is such that many questions will be inevitably raised in actually executing the solution. But because of its theoretical validity, it remains as one of the better attempts to allocate highway program costs among different classes of users and types of vehicles.

Gross Ton-Mile Solution

Because the incremental solution requires extremely elaborate computations and because of the difficulties involved in its execution, there has been a growing tendency to use another solution, the gross ton-mile solution. Many authorities have noted that weight, size, and distance are among the more important factors which determine highway costs. It is believed by many that the ton-miles reduces them to a common unit, and gives expression to a measure of relative use and, therefore, relative value. Many have looked to the ton-mile solution as a pragmatic approach to the incremental solution (18).

Basically, the idea underlying the ton-mile solution is that each weight class of vehicles should be assessed tax responsibility on the basis of the total ton-miles traveled by the average vehicle within each class. Relative use is then assumed to be proportional to the benefits received, and ton-miles are assumed to be an accurate measure of relative use. This is tantamount to saying that ton-miles are a measure of benefits received.

It should be pointed out that the gross ton-mile method does not necessarily imply that there should be a single equal rate per gross ton-mile for all vehicles. What is suggested is that all user taxes (gasoline taxes, registration fees, and third-structure taxes) should add up to the amount necessary to make the price of highways the same per ton-mile for all classes of motor vehicles.

This method has the virtue of simplicity. Once vehicles are divided into weight classes, the average vehicle weight in each class is multiplied by the miles traveled, and tax responsibility is distributed in proportion to this product.

Two alternate methods are possible in executing the ton-mile solution. One alternative is to compute the gross ton-miles for each weight group of vehicles, and then to allocate the entire user tax burden in proportion to the gross ton-miles of each weight group without considering the individual highway systems. The other method is to calculate the gross ton-miles traveled by the vehicles in each group on each of the several road and street systems. The greater the subdivision of systems, the greater will be the accuracy of the method.

Advantages.—The ton-mile method assumes that all highway costs are joint costs, and that the costs were incurred for joint use by mixed traffic. The extent to which special costs have been incurred because of the existence of heavier vehicles is, according to some authorities, a moot question. The number of variables involved are too numerous to permit allocation on this basis. The measure that represents the relative amount of service from highways is allegedly superior to the incremental approach and, it is believed, the gross ton-mile is therefore a proper approach (9).

The merits of gross ton-mile are set forth in a study by the Colorado Highway Planning Committee:

> The theory of gross ton-mile taxation assumes that the movement of one ton one mile over a public highway constitutes a basic unit of transportation service and highway use. Given this assumption, it follows that the benefits received by each class of highway users are proportional to the use made of the highways, measured in ton-miles.
>
> If the sum total of highway benefits are considered to be measured by ton-miles of highway use, the principle of equal payments for

> equal benefits received requires that each highway user pay approximately the same user tax for each ton-mile of the use made of the highway system. In effect, ton-miles of highway use, or highway benefits are for sale to highway users. A vehicle traveling over a highway is utilizing ton miles of service and receiving ton-mile benefits. Each ton-mile should logically command a price for the user in the same way that each article for sale in a department store has a price. But since it is assumed that the cost to the government of producing facilities for one ton-mile to a highway user is approximately the same as the cost of any other user on the same section of road, then each ton-mile purchase should bear the same purchase price. When the user-tax structure is altered to accomplish this end, all highway users . . . will be paying for benefits received. The relative share of highway user tax responsibility for each user would be his proportion of ton-miles of travel relative to the ton-miles of travel over the highway system. (12)

The Colorado study suggests that one of the chief merits of the ton-mile method is that other methods of tax apportionment, which might be founded on sounder principles of public finance, are ridden with factual weaknesses. Measures of relative use of highways, which take into account factors other than weight and distance, are likely to lack the factual background for a reasonable application. The Colorado investigators believed that the ton-mile theory combines the two most important measures of relative use, and for this reason a close approximation to highway benefits is obtained. They felt, also, that the idea of a price paid for a ton-mile benefit received was a concept both logically grounded and easily understood. They concluded ". . . the existing state of opinion and data on the relative use of highways does not warrant a more complex method than the gross ton mile." (12)

The virtues of simplicity and ease of calculation have been two of the main factors contributing to the influence of the gross ton-mile solution. Since the first study based on gross ton-miles in 1944, the method has been applied extensively at virtually all levels of government. An additional reason for its popularity is that the method tends to produce a sharper graduated schedule of tax responsibility for the successive weight groups than does the incremental or most other methods. A number of investigators may have been led to advocate the ton-mile theory because of their feelings that heavier vehicles were escaping taxation for which they should be responsible. It is not a predetermined plan that the ton-mile theory will result in higher taxes on heavier vehicles than other methods, but it frequently does. This likelihood may have contributed to the popularity of the method. Some authorities have employed the theory believing that it sets an upper limit to the level of taxes which should be assessed against large vehicles. Taken in this context, and compared with other solutions, which assign a lesser share to large vehicles, the ton-mile theory is useful (5).

Although many have looked on the ton-mile theory as the answer to cost allocation among classes of users, there are numerous pitfalls involved in its application. Some attention must be given to the limitations which must be placed of the results of the solution.

Shortcomings.—As indicated in the preceding section, the ton-mile method assumes that ton-miles reflect relative use and thereby reflect relative benefit or value received. An example will show the fallacy involved in this contention. According to the ton-mile measure, 20 passenger cars each weighing 2,000 lb would receive as much highway service value as one truck having a gross weight of 20 tons. It is clear that in this case equal ton-miles do not necessarily result in equal benefits (11). (This type of example is used by many authorities.)

It is also clear that, in the example, the 20-ton truck would require highway design standards substantially in excess of those necessary for the 20 passenger vehicles. On the basis of cost responsibility, then, the truck might possibly have a greater burden allocated to it than would be the case using the ton-mile.

Koenker and Larson point out another weakness of the ton-mile method:

> The other weakness of the ton mile approach is that it assumes the same tax charge should be made for haulage over any kind of highway whether surfaced or unsurfaced. This results in vehicles which never use certain types of highways having, nevertheless, to pay for these in proportion to ton miles traveled on the entire system. (11)

Along the same lines, the product of weight × distance would be a valid unit of measurement of value received if all vehicles traveling on highways were transporting goods for specific remuneration. A passenger car and a heavy commercial truck, however, travel the highways for purposes which are entirely different. Hall has pointed out that a light panel delivery truck loaded with bread could easily receive the same money value as a heavy truck loaded with dirt for a trip of the same length (13).

It is clear that gross ton-miles, although they may be a measure of highway use, are not a measure of value nor are they a measure of benefits received. This fact points to the fundamental weakness in the ton-mile theory inasmuch as the theory must assume that ton-miles do measure relative value or benefits.

Another school of thought views the ton-mile as a kind of physical unit, like a foot-pound. It has been suggested by some that the ton-mile defines the energy absorbed by transportation. This contention, like the contention that ton-miles measure value, is not valid. This can be illustrated as follows:

> That this concept is entirely untrue can be demonstrated simply by pointing out that it would take at least twice as much gasoline to propel ten 3,500 lb. passenger cars one mile as it would to move one 35,000 lb. truck the same distance. This is true because the rate of gasoline consumption varies much less than proportionally with gross weight. Gasoline consumption, however, is a measure of energy and absorption. Thus, the supposed physical basis for the ton mile unit vanishes upon analysis. (5)

For these reasons, the ton-mile is not a satisfactory measure of value or benefits. This is not to say, however, that ton-mile taxes are inappropriate in all instances. The essential point is that to allocate the entire user responsibility among classes of vehicles on the basis of ton-miles rests on an assumption which is not valid. The ton-mile is employed in some of the other solutions as being appropriate to the allocation of certain costs. And, in some places, it may be appropriately used. As previously indicated, ton-mile apportionments sometimes result in cost assignments which exceed the ability to pay of heavier vehicles. For this reason, some have suggested that the weight factor should be tapered in the upper ranges of the scale involving heavy trucks and buses. Thus, in translating the results of the ton-mile allocation into practical policy guides, a serious difficulty is posed. It would not be correct to employ the results of the method if it resulted in great inequity in terms of ability to pay, as well as decreased governmental revenue for highways (9). This question is partly one of public policy. There may be, in some cases, good reasons for wishing to discourage the operation of heavy vehicles. A tax based on ton-miles might be one way of accomplishing this. This objective, however, is not usually sought.

Many factors which determine highway costs are not related in any way to gross weight. Required pavement thickness, for example, varies with the wheel load, not with gross weight as would be the implicit assumption in the ton-mile method. Road costs also depend partially on climate and other natural conditions. These conditions are not related to the characteristics of vehicles—much less to the ton-miles traveled by vehicles. Finally, some road costs such as landscaping are usually solely for the benefit of passenger cars. This aspect of highway costs is ignored by the ton-mile method.

In translating the results of the ton-mile solution into a tax system, the essential idea is to equalize payments per gross ton-mile. Doing so overlooks the fact that road costs per ton-mile are different for different classes of highways. An equalized tax per ton-mile is likely to discriminate against intracity users in favor of intercity users.

Those who advocate the gross ton-mile theory believe it to constitute a valid measure of benefits received. It must be realized, however, that the ton-mile method is not a scientific one, for its basic hypothesis rests on assumptions which are not valid. To make this ascertion about ton-miles is not to cast a dubious type of criticism; rather the facts clearly indicate the theoretical weaknesses of the method.

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