Comparison of Incremental and Ton-Mile Allocation Methods

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● THE 1955 MONTANA legislative session established an interim group, Fact Finding Committee on Highways, Streets and Bridges, for the purpose of studying the highway problem in the state and making recommendations to the legislative assembly which would convene in January, 1957. The committee was directed to study highway matters concerned with management, long-range costs, motor vehicle taxation, and the assignment of costs between motor vehicle users and other beneficiaries; the determination of a tax base for motor vehicle users, a complete classification of highway systems in the state, and other matters relating to legal problems, transport economics, and the allocation of highway revenues among the various government units in the state.

One of the more interesting aspects of the committee's work dealt with the allocation of highway costs among the various users. This was a particularly pertinent subject in Montana, since the state has inaugurated a seven cent gasoline tax, making passenger car payments relatively heavy in relation to a rather moderate rate fee schedule for commercial vehicles. The legislative assembly appeared to be particularly concerned about this problem and desired the best facts obtainable for a reasonable cost allocation.

It would have been desirable to perform a cost-function analysis, an incremental analysis, and a ton-mile allocation; but, because of the time restrictions and lack of sufficient accounting detail, it was decided not to perform a cost function analysis. The effort was devoted to arriving at comparative allocations by the ton-mile and incremental methods.

Montana sought simplicity of calculation coupled with reasonable accuracy rather than precise measurement in both the ton-mile and incremental allocations. At best, the most precise analyses produce nothing more than measuring sticks to be applied to the tax allocation problem. Often pure theoretical considerations obscure the practical reality of the problem. No philosophy of motor-vehicle tax responsibility is without its shortcomings. In Montana, the increment theory, probably the most supportable of all theories, appears to fail in at least one major respect, to provide a fair or reasonable allocation of road costs to all vehicles. In this state, with its tremendous mileage of secondary and local farm roads serving a sparse population and low traffic, it is necessary to subsidize these facilities with earnings, in excess of the state's cost, produced by vehicles traveling the primary highways. This subsidy is probably just because the provision of primary roads is dependent upon the state's ability to pay, which, in turn, is largely dependent on farm income. However, farm vehicles perform the larger amount of their travel on secondary and local roads (roads with little or no weight-cost elements); thus, the responsibility of heavy farm trucks by the incremental method is less than that of heavy commercial trucks which mainly use the high-weight-cost primary highways. Farm vehicles do not incur so much cost in proportion to their weight, but, since they are subsidized, should they be treated differently from the subsidizing vehicles? It appears that a benefits philosophy must be incorporated to produce a fair tax structure. In fact, a combined system application of the ton-mile theory will result in a similar array of charges against farm and commercial vehicles (on a per mile basis) because their operating gross weights for a given size of vehicle do not differ materially. It has been stated that relative benefits are not validly measured by a ton-mile analysis because of differences in the specific remuneration derived from the transport of weight from the lightest passenger car to the heaviest tractor-trailer combination. There may be some validity, however, in a comparison of the responsibilities of farm trucks and commercial trucks of the same weight on a ton-mile basis. Both derive economic gain somewhat in proportion to the load they are able to carry. The amount of remuneration must, in both cases, be sufficient to underwrite the operating

expense and depreciation on the respective vehicles. (Taxes are a small proportion of the whole burden.) The element of profit is probably similar—at least the farmer earns enough to warrant private rather than for-hire operation. Thus, it may be argued that a ton-mile comparison of the benefits received by these two types of vehicles from roads in general is valid. Whatever the outcome from theoretical consideration, the resulting tax structure must be largely a matter of state policy. All that can be required of the tax analyst is that he provide the legislators with firm measuring sticks based on philosophies that are generally acceptable. The amount of precision applied to any of the approved tax-allocation methods need only be sufficient to assure results that are reasonably accurate and consistent with the applied philosophy.

Both the incremental and ton-mile methods have been used by the Montana Fact Finding Committee on Highways, Streets and Bridges to allocate the costs of a program of construction designed to provide the state with an adequate highway and city street system twenty years hence. The needs and costs analyses were performed by engineers of the State Highway Department with the Automotive Safety Foundation as consultants. Financial studies performed by the committee disclosed that the continuation of present tax schedules would provide sufficient revenue, substantially, to finance the new highways under a long range (32 year) fiscal program. Standard statistical methods of estimate were applied to this determination. (It must be remembered that the bulk of motor-vehicle-user revenue is derived from the fuel tax. Any adjustment of "weight" taxes in the interest of equity will not produce a large change in revenues proportionately. Within the limits of the accuracy of a statistical forecast, the amount of revenue produced for the period will be dependent on the level of taxation imposed on passenger vehicles which is largely governed by the amount of fuel tax.) Accordingly, the amount of cost allocated in the mid-program year was designed to return revenues in twenty years approximately equivalent to those anticipated from the continuation of present taxes. A motor-vehicle-user share of this cost was determined from a practical interpretation of the results of an earnings-credit analysis. Although a theoretical division of responsibilities between motor-vehicle-users and non-motor-vehicle-users was derived by the earnings-credit methodology for each separate highway system, there was no practical significance in the results because of the aforementioned necessity to subsidize secondary facilities by the excess earnings of primary facilities.

Consistent with the benefits philosophy of the gross ton-mile theory; because of intersystem subsidies and interrelated benefits; and because incurred cost is not a factor, all systems were combined for the ton-mile allotment. In the first place, Federal-aid was subtracted from program construction, maintenance, and administration cost, and a user proportion of the remaining state's share, which would return the required revenue in twenty years, was determined. Traffic was projected to the mid-year by groups of indices based on historical trends in registration and vehicular travel. It was assumed that gross operating weights would remain constant for the same registered gross vehicle weights (for lack of specific information to the contrary). The user share of program cost was distributed to different vehicle types by registered weight groups in proportion to ton-miles traveled, and the results were converted to rates of charge per vehicle mile. The first measure of relative responsibility produced, not unexpectedly, a lower charge against passenger vehicles than they are paying under the present fuel tax and registration fee. The assessment against heavy commercial vehicles was higher than that derived by the incremental method but was mitigated by equalization of responsibility between commercial and farm vehicles. The incremental method actually produced responsibility rates for farm trucks which would be entirely met by their present fuel tax and registration fee contribution.

One of the most important measures was a determination of the present taxes paid by all vehicle types on the streets and highways of the state in 1955. The existing tax structure was broken out in fine detail. Annual traffic was estimated for vehicle groups enjoying tax privileges by paying a percentage of regular weight fees: 75 percent fee groups, 60 percent fee groups, and 20 percent fee groups. A further breakdown of traffic was subscribed to vehicles registering annually and to those registering semi-annually who pay half-year registration and weight fees. Tax contributions were calculated for each vehicle type in each of these divisions, and the results were reported

on a per vehicle-mile and a per ton-mile basis. The annual mileage, fuel consumption and weight data for these calculations were gathered from several sources. Most significant sources were loadometer and traffic studies, a 1953-54 road use study with a supplemental truck sample, and a special study of truck and combination vehicle usage and fuel consumption in which field data were collected by the Montana Motor Transport Association. The annual contributions for each group of vehicles were added to obtain total highway user contributions for the year. This total was within 3.5 percent of user revenue collected in 1955, thereby lending considerable support to the assumptions used in the analyses.

In connection with the analysis of revenues contributed under the existing tax structure, it became necessary to develop gasoline and diesel fuel consumption curves. Some data for the gasoline curve were available from the road use study. Additional data were developed for this curve as well as the diesel curve by measurement of fuel usage on controlled operations. These operations were actually "over the road trips" of various vehicles in which gross weight, mileage, and fuel consumed were measured accurately and recorded. The number of diesel fuel observations were sufficient to permit the fitting of a reasonable reliable consumption curve. The gasoline data were so limited that the reliability of the fitted curve might be questioned except that the resultant curve falls close to similar curves developed in Highway Research Board Bulletin 92. The curves developed for the Montana study are shown in Figure 1.

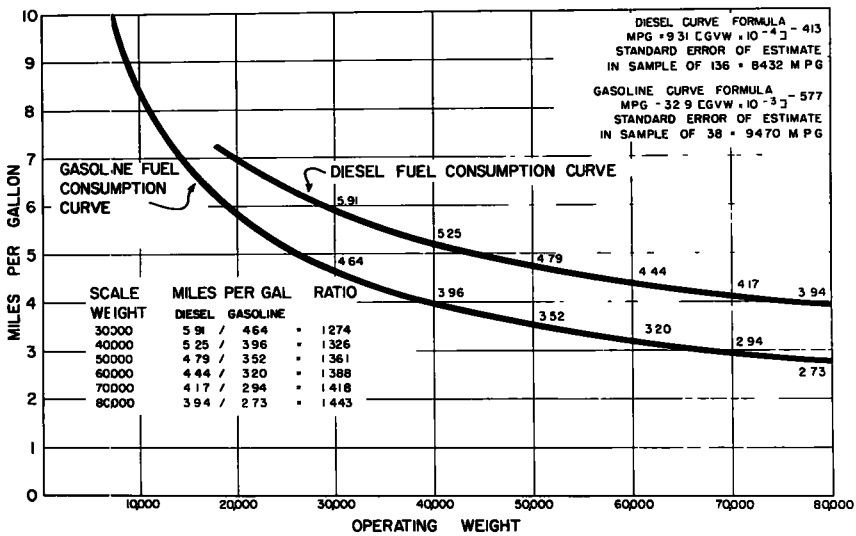

Figure 1. Comparison of average fuel consumption, gasoline vs. diesel powered vehicles State of Montana 1956.

The Montana incremental analysis was especially designed to fit the peculiar highway needs and traffic conditions in this state. While the basic theory was the same as that of the orthodox incremental procedure, a straight-line, rather than a triangular or rectangular solution was devised. A basic premise was interjected along with the usual considerations—that, from an historical viewpoint, all lower-standard roadways are stages in the construction of higher-standard roadways, and, therefore, may be considered to be incorporated in the structural and geometric composition of higher-standard roadways. Engineering judgment provided the basis for a formularized relationship between traffic volume and the magnitude of repeated axle loading to be expected on the newly designed facilities. An intermediate roadway (whose structural standards would not be influenced by climatic conditions) was related to a vehicle of intermediate size and weight which it would accommodate. Its structure would be of sufficient strength for the axle loads imposed; its geometrics would be adequate for the dimensions and speed limitations of the associated vehicle. This basic mean relationship was established between a five-ton truck imposing a 6,000-lb axle load and

the standard of roadway accommodating from 200 to 400 vehicles daily. Additional relationships were formulated between larger axle loads, considered to be representative of vehicular size as well as weight, and highways designed to accommodate successively more traffic volume. Thus a 10,000-lb axle load was related to facilities designed to carry 400 to 1,000 vehicles daily; a 14,000-lb axle to facilities designed to carry 1,000 to 2,000 vehicles daily; and an 18,000-lb axle to facilities designed to carry more than 2,000 vehicles daily.

Incremental costs were determined by subtracting the average cost of these facilities, as determined from the Automotive Safety Foundation needs study, one from another, system by system. The following is an example of this determination: an increment of structural and geometric cost was obtained by subtracting the cost of the designed primary facility for 1,000 to 2,000 vehicles daily from the cost of the designed primary facility for over 2,000 vehicles daily. This amount of cost was charged to vehicles imposing the 14,000- to 18,000-lb axle loads, whose repetitions were considered to have demanded the structural strength employed in the higher-standard roadway design, and whose magnitude defined the size of vehicle demanding the geometrics employed in that design.

A careful consideration of all aspects of geometric cost related to vehicular size and weight was imperative for due support of the procedure. Although geometrics could not be related to a vehicle's size with the same precision that structure could be related to an applied axle load, it was possible to demonstrate a reasonable distribution of geometric cost by weight, when combined costs were used to develop incremental costs by the method utilized.

There was not a large differential in right-of-way costs between different standards of two-lane facility designed to carry more than 400 vehicles daily, and the differences that did occur were subscribable to the improvement of geometrics rather than additional width. Accordingly, right-of-way cost was combined with other geometric and structural costs for the calculation of increments.

Maintenance costs for different roadway designs were derived in the needs study by use of factors based on highway department experience. These costs were found to vary with the standard of highway constructed, so that the highest type of facility would cost slightly less to maintain than the next highest type. It followed, therefore, that vehicles charged with a high standard of construction should benefit from maintenance savings. It appeared that all factors would be properly weighted by the simple expedient of combining maintenance and construction costs. Those maintenance costs which are not affected by the standard to which the roadway is constructed, such as the costs of snow or slide removal, slope protection, weed and brush control, ditch cleanout or off-road drainage work, would be automatically excluded from increments obtained by the subtractive process. Where improved highway standards would result in maintenance savings, increments of construction cost chargeable to large and heavy vehicles would be correspondingly mitigated.

Some administration cost (the direct engineering cost of contract construction) was included with other construction cost upon which it would depend.

From the foregoing description, it may be seen that incremental costs, as developed by the Montana method, accounted for most items of total road expenditure by a simple mathematical process. However, this process was warranted only after advance consideration of each item separately; that is to say, of the relative amounts of each item that would be charged to successively heavier vehicles by combining costs. It is not within the scope of this paper to enter the considerable argument advanced in the Montana technical report.

Having obtained increments of combined costs which were reasonably associated with the requirements of vehicles of different sizes and weights (as measured by their axle loads) these costs were distributed in much the usual manner. Each incremental cost, determined on a per mile basis, was applied to a total mileage of increment in the study system, which included roadway where the increment is to be the uppermost part of the paved structure and roadway where the increment is to exist as part of a higher standard structure. The total incremental cost was distributed among vehicles imposing axle loads of a size to require that amount or more structure. A weighting

procedure was incorporated in the distribution; where each successively larger axle, to the limit of accommodation of the structural increment, was charged with a greater share of incremental cost for the same amount of travel. For differing travel, an additional factor was inserted which was determined from a mathematical relationship between volume of traffic and associated axle load design.

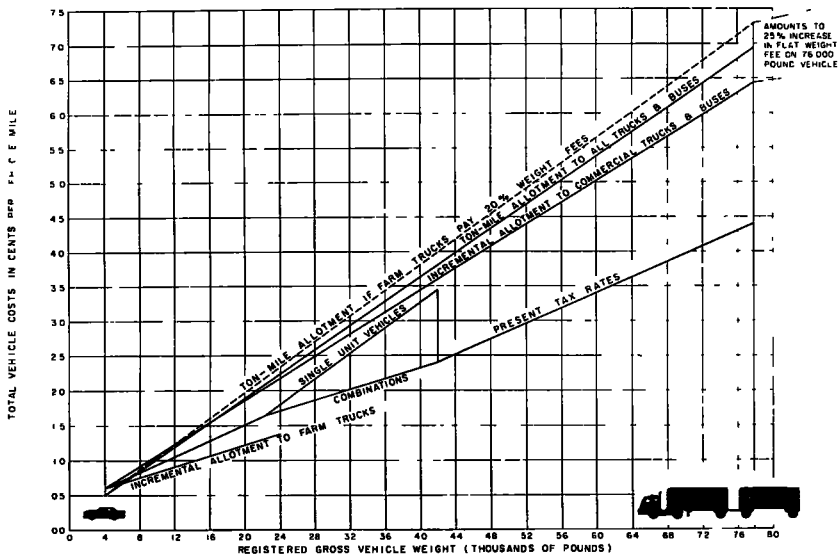

Figure 2. Comparison of responsibility allotments & 1955 taxation in Montana.

A summation of axle miles of travel on Montana's highways disclosed that the logarithm of axle miles increased as design load increased (assuming the empirical relationship between volume of traffic and repeated axle load). In exponential terms axle miles are proportional to a constant raised to a power equal to the load for which the structure is designed. Thus, by dividing the travel of each axle by the constant raised to the load term, the relative load value of travel may be determined. This factor was used to weight the loads on each increment, and the cost was distributed between the weighted loads according to their relative magnitude.

Three increments of cost above the basic mean standard were determined to be the responsibility of three groups of axle loads larger than 6,000 lb. By extrapolating the relationship between weighted load and incremental cost downwards, an undefined increment of structural cost was developed for assignment to all axle loads larger than those imposed by a passenger car. There was no particular theory behind this latter manipulation. It is logical to assume that costs proportional to size and weight, being established from one point upwards, would extend downwards on the same curve to a point where weight is a common denominator. These practical results are desirable for the determination of a tax structure.

The sum of weight costs for the road system, determined and distributed in the manner described, was subtracted from the total cost of the system to obtain the cost of the basic facility of the system, which would be required by all vehicles and which was distributed in proportion to travel. Remaining administrative cost was distributed, likewise, in proportion to travel.

Each of the three highway systems was handled separately by the method outlined - the proposed interstate system, the proposed state highway system, and the proposed secondary system. Urban streets constituted a fourth system. It was assumed that the costs incurred by heavy vehicles on urban state highway extensions would be in the same proportion as those incurred by heavy vehicles on rural state highways; and that the costs incurred by heavy vehicles on arterial streets would be in the same proportion as those incurred on rural secondary highways. Distribution of urban costs was based

on these assumptions. Local city streets and local rural roads were not treated by the incremental method.

Structures were taken as comprising a fifth system. Axle load was again the measure of both weight and size. The minimum standard for stability was H 10 structural design. The difference between H 10 and H 15 structures was considered to be required by axle loads over 16,000 lb. The difference between H 15 and H 20 structures was considered to be required by axle loads over 24,000 lb. Trailer axle loads, since trailers were studied as separate vehicles in the analysis, were rated at 75 percent of their value, which positioned a combination vehicle in the right order, relatively, with respect to a single unit vehicle. The two increments of weight cost were determined for a weighted average width of structure. The distribution of these costs was on the basis of weighted travel - the factor being the difference in magnitude between the weight of the vehicle's axle and the largest axle in the next lowest increment. Two feet of width of the H 10 basic element in the H 15 and H 20 structures were charged to vehicles weighing 5 tons or more. The remaining cost of H 10 elements was charged to all vehicles in proportion to their travel. The cost distribution was not unlike that devised for roadways.

After relative charges were determined, Federal-aid was subtracted from each system separately as a uniform percentage of all charges. Then, total charges were assembled and reduced by a percentage so that the required user share of program cost would be produced. Figure 2 shows the results of the incremental allocation compared with those of the ton-mile allocation.

It had once been thought that Federal-aid funds should be subtracted in advance of responsibility determination. However, where interrelated maintenance and construction cost have been combined by the Montana Incremental Method, determinations which follow are applicable only to an integral highway product containing all construction cost and all maintenance cost. Besides, it is sound in principle to determine proportional responsibility for the total product, and then, in effect, to apply this proportion to the state's cost alone.

A weight-distance tax schedule and a flat fee tax schedule, both based on the incremental determination, have been presented to the 1957 legislature as a result of this analysis. In addition, the lawmakers have been provided with two other measures by which to evaluate the tax policy. The one is a ton-mile allocation of responsibility with due explanation; the other is a complete breakdown of taxes paid by every vehicle type under the existing tax structure. It must be admitted that the tools provided for establishing equity in highway user taxation are at best blunt instruments. Rather than arriving at precise responsibilities, they merely provide a zone of responsibility within which a particular vehicle can reasonably be expected to fall. The several tools have been provided in this instance in order that the lawmakers will have a gauge of the size of the zone of responsibility.

One of the advantages of the ton-mile allocation of costs is the simplicity with which it may be applied and the relative availability of the necessary data. Perhaps the greatest disadvantage in the incremental method is the difficulty of obtaining precise information and of developing all the necessary cost breakdowns and traffic data that is essential to a competent study. While the ton-mile allocation in Montana does result in a more severe allocation to heavy vehicles and a fairly sharp reduction of charges against the passenger car, it does provide an allocation that runs in the same order as incremental cost responsibilities. This fact, along with the possibility that across the board ton-mile allocation may be more fair in the case of the substantial subsidization of local roads, seems to lend credence to this type of allocation in a state such as Montana. There is certainly an indication that the ton-mile results have substantial validity, and if time and data were not available for a more complex incremental analysis, the use of a ton-mile allocation would not be entirely inappropriate.