Initial Problems Confronted in the Kentucky Incremental-Cost Study

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EVEN though the investigation of the highway-finance background in Kentucky, looking toward economical distribution of expenditures, sound methods of taxation, and wise choice between current revenues and borrowing as initial financing measures, is well under way, the problems of the distribution of the highway-user tax load among various classes of vehicles on the basis of an incremental-cost study are as yet confronted only in the planning stage. Thus, the following discussion of Kentucky thinking on the definitions of "basic road" and "basic vehicle," the classification of highways for incremental-cost study, and the treatment of maintenance expenditures in the light of Kentucky policies and methods must be regarded as distinctly preliminary. One fundamental purpose of the explanation is to invite criticism looking toward possible revision of the staff's outlook.

Although the point is only incidentally important to the problems mentioned, perhaps one should recognize that the Kentucky incremental analysis will be wholly in terms of projections to 1964-65. This fiscal period is accepted as representing a typical year within the program time span envisaged by the Automotive Safety Foundation.

DEFINITION OF "BASIC ROAD" AND "BASIC VEHICLE"

In Kentucky, as in other states which have attempted an incremental analysis, the decision regarding what is the "basic vehicle" and the "basic road" is of paramont importance and of considerable difficulty. In the Kentucky study, a basic vehicle is arrived at by the process of calculating backward from the basic road, that is, the definition of the basic road simultaneously determines the basic vehicle.

Members of the staff of the state highway department who collaborated on defining the basic road believed that it is determined by weather conditions. The state experiences a severe winter one year in four or five. It is not economical to design surfaced roads that will withstand, in excellent condition, this occasional frost; rather, the department designs the road to a lower standard and then bears the higher maintenance costs which ensue. But the road must be good enough to remain in operation and not be damaged irreparably by severe frost. Design standards established by these considerations determine, for any traffic-volume system, the basic road for that traffic-volume system. Working backward from the basic road, it is possible to determine the axle loads that a road designed to these standards would bear, and thus to arrive at the basic vehicle. To put it more specifically, the basic vehicle is one having axle loads no greater than those the basic road can withstand when used in keeping with the traffic volume normal to the particular system.

This treatment of the problem seems to be more realistic than the usual method of defining a basic vehicle in terms of a given axle load and then defining the basic road on each volume system in terms of that basic vehicle. Fundamentally, it means that the increments in cost on each density system are based on the cost of a road of minimum design standards in the sense that the Kentucky Department of Highways would not build a road of less-rigid specifications under any circumstances. In all probability this method of determining the basic vehicle will mean that the first axle-load class will extend to a weight considerably greater than is usual in studies of this type.

CLASSIFICATION OF ROADS FOR INCREMENTAL STUDY

In an incremental-cost study, it is essential that increments in pavement design standards be based on both axle loads and traffic volume. The Automotive Safety Foundation needs study, now nearing completion in Kentucky, has defined the standards for grade, curvature, and structure on each of three administrative systems of rural highways:

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[1] The author's colleague, Virgil Christian, and W. B. Drake, of the Kentucky Department of Highways, have aided in the preparation of this paper.

state trunk-line, county arterial, and country feeder roads. Within each of these systems, design standards were established on the basis of traffic volume. These standards for each section of road were determined by two considerations: the administrative system to which it belonged and the volume of traffic on it.

The method of classification, when followed in Kentucky, led to 14 basic design standards for rural roads. To make matters worse, from the viewpoint of an incremental analysis, various modifications in trunk-line and county-arterial standards were necessitated by the wide differences in terrain throughout the state. Also, street design involved some departure from rural standards, especially in geometrics. When these modifications were counted, a grand total of 34 clearly identified standards resulted.

It is impossible to obtain traffic data in the detail that would be required to make an incremental analysis on such a vast scale. If such figures were at hand, the amount of calculation required would be prohibitive. It was decided, therefore, that highways with the same design standards would be combined, regardless of the administrative system in which they fell. This occasioned no serious difficulty, as the design standards did not vary greatly among administrative systems for given traffic volumes.

The traffic groupings in vehicles per day that most nearly satisfied the combined standards with a minimum number of categories are: 0 to 99; 100 to 399; 400 to 999; 1,000 to 1,999; 2,000 to 2,999; and above 3,000.

MAINTENANCE-COST PROBLEM

The determination of maintenance costs and the construction of maintenance-cost indexes present many problems of extreme practical difficulty. For example, if the calculation to be made is in terms of maintenance costs per mile for a given traffic-volume system, what can be done about the fact that the state's roads in that system have varying widths of pavement, of shoulder, and of right of way? A reduction factor is not feasible, because maintenance costs, as studies made by the Bureau of Public Roads indicate, do not vary functionally with road width. Yet it is hardly plausible that road width has no bearing at all.

Several alternative courses of action seem possible:

1. One can classify the sample of maintenance-expenditure data from each system by road widths, prepare estimates for maintenance cost per mile by road width, and then test for significant difference by comparison of averages and of dispersion or by analysis of variance techniques. If there is no significant difference, this implies that road width is of negligible importance relative to other factors for that traffic-volume system and can be ignored. If the difference is significant, it will be essential to prepare separate estimates for the different road widths and combine these in the final estimate by weighting each in proportion to the number of miles of that width in the system. This approach appears promising. But as the department has not yet completed maintenance record tabulations for the selected subsections of road, one cannot be sure that the conditions for the analysis of variance study are met.

2. If road width varies only slightly within lower traffic-volume systems, one can ignore it. On higher-volume systems, separate estimates must be made, at least, for two- and four-lane roads. Variations in width on these highways, however, can be ignored.

3. Separate estimates for pavement maintenance and for other maintenance expenditures would be essential. Within a given traffic volume system it is probable that expenditures for pavement maintenance would vary directly with road width, but those for shoulders would vary inversely. Should these two variations approximately offset each other, then ignoring road width would seem feasible; if not, then the separate estimates would be combined to arrive at a final average estimate applicable to the entire traffic-volume system.

4. Highway engineers by examination of maintenance expenditures might develop "judgment" maintenance-cost indexes independent of statistical analysis.

A second problem in connection with the construction of maintenance cost indexes is that of reconciling road age as it affects these costs with road age as recorded on the state's maintenance records. The department classifies a road as new after reconstruction, and reconstruction may mean 0.75 inches or more of resurfacing without alteration in subgrade and other cost factors having vital importance in road life and in other ways bearing on the expenditures required.

Even the third task of translating a definition of maintenance cost into usable terms is quite difficult. A theoretical definition, as "the cost... of preserving, within practical limits, the carrying capacity of existing roads" would include costs which differ appreciably from those shown on state maintenance records. Indeed, there would be heavy maintenance costs, as thus defined, on many sections of road on which only minor sums were spent during a given year and the reverse. To elide this aspect of the problem, maintenance expenditures for an average of 4.5 years, rather than maintenance costs, can be employed. This means essentially an attempt to assign responsibility for funds actually spent on maintenance.

A fourth problem as to maintenance expenditures has two distinct aspects: (1) What proportion of total maintenance expenditures are weight function expenditures? (2) What proportion of the weight function expenditures should be allocated to vehicles of each different weight and type? To get a preliminary basis for answers to these questions, a probability sample was taken from the maintenance records of the state highway department. Statistically, each section of road was put into one of the six traffic-volume systems. The six universes were then sampled at random, the size of the sample from each being determined by the usual statistical consideration.[2]

An ideal solution would involve expressing maintenance expenditure per mile as a function of age of the road and the number of axle miles of each axle-load increment to be used in the study. This would yield a multiple regression equation with expenditures per mile as the dependent variable and age of road and axle miles of each different axle-load increment as independent variables. Unfortunately, in this particular equation the independent variables, except age of road, would themselves be highly correlated; so the results of the analysis would consequently be quite unreliable. Specifically, if the number of axle-miles of the basic axle load is highly correlated with the number of axle-miles in the other axle-load increments (and that is most assuredly the case), then there is little basis for measuring the separate influence of each on maintenance expenditures. This limitation, incidentally, seems to preclude the use of a multiple regression equation to develop maintenance-cost indexes, not only in Kentucky but in any state, since it is inconceivable that the number of axle-miles of any given axle load would not be correlated with total traffic and thus with axle-miles of other axle loads.

This does not mean, however, that the expenditure records taken in the sample cannot be used to provide valuable information. A regression analysis involving maintenance expenditures as the dependent variable and total vehicle-miles of travel as the independent variable should provide a basis for making the decision as to what proportion of maintenance expenditures is a function of highway use. Perhaps a more useful approach would be to treat age of road and total vehicle-miles of travel as independent variables, with maintenance expenditures as the dependent variables, and then, using partial correlation analysis, find the effect of vehicle-miles on maintenance expenditures "net" of road-age influences.

It would be well to emphasize, however, that one cannot depend exclusively on the results of any contemplated statistical analysis. In the first place, the maintenance records as kept by the state highway department are admittedly not absolutely correct, and the maintenance expenditures upon which the analyses will be based will therefore be more or less incorrect.

Secondly, there is the possibility of error in the traffic estimates which will be used as one of the variables in the regression equation. This is in nowise a criticism of Kentucky's traffic data. As indicated by Hugo Duzan, of the Bureau of Public Roads, these data are much better than those in the average state. Even so, the statistics fall far short of an actual count on all the roads and streets of the state.

Thirdly, there is the difficulty, already mentioned, of determining accurately the age of a road.

Fourthly, there is possible sampling error. The sample was designed in such man-

[2] Specifically, standard deviation and measures of skewness and kurtosis.

ner that the chances are nineteen to one that the error in the estimates will not be more than 10 percent of the estimates themselves, and it will in all probability be less; but we cannot ignore entirely that one chance in twenty. Actually, the sample from each traffic-volume system is large enough that the sampling error should be negligible compared with the likely errors in estimating road age and traffic.