Methodology of the Kentucky Incremental Analysis

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● CERTAIN initial problems confronted in the Kentucky incremental analysis were discussed in a paper presented to the Highway Research Board at the 1955 meeting by Professor James W. Martin, Director of the Bureau of Business Research at the University of Kentucky. In that paper Professor Martin dealt with matters relative to the definition of *basic road* and the *basic vehicle*, designated the standards by which Kentucky roads were classified for incremental study, and set forth possible alternatives for handling issues related to the incremental treatment of maintenance costs. Some additional problems which necessitated departures from the usual methodology of an incremental analysis have arisen subsequent to that time. These latter problems, together with the resolution of the maintenance cost question, provide the subject for this report.

The preparation and projection of traffic estimates is one of the critical phases of any incremental analysis. It is also a phase into which appreciable errors may be introduced since the information used in making the estimates must necessarily be obtained on a sampling basis. The method employed in many states has been that of projecting motor vehicle registrations and average annual mileages, by vehicle type and registered weight, with their product representing total vehicle mileage for each category. But this procedure requires detailed registration statistics, and these unfortunately were lacking in Kentucky because the state registers by weight alone rather than by vehicle type and weight.[1] Moreover, a 1954 Kentucky Motor Vehicle Use Study, which would have been the only source of data for determining average annual mileages, was not designed in such way as to give reliable estimates for individual registered weight classes. Stated in more technical language, the cluster sampling plan used in that study led to standard errors which were satisfactorily low in terms of the total sample for any vehicle type but which might be quite large for individual weight classes within that total sample. And finally, the method would have required the assumption that travel by domestic vehicles in other states approximately balances travel by foreign vehicles in Kentucky, by registration class, and this was an assumption which could not be held in the face of considerable evidence to the contrary.

The decision was made, therefore, to use traffic counts made by the Division of Planning of the Kentucky Department of Highways to establish both the volume and composition of present traffic and to provide a basis for projecting them to the program year. Data from manual counts, loadometer stations and automatic traffic recorders were combined to yield the final estimates; over 4,000,000 vehicles were included in the counts from which the breakdown of traffic by vehicle type was made. The counts, by traffic volume, were as follows:

Average Daily Traffic	Vehicles Counted
0-399	13,178
400-999	54,807
1000-1999	197,092
2000-2999	426,623
3000 up	3,729,263

If these counts are considered to be random samples from the traffic stream on the respective incremental systems they are evidently large enough to yield thoroughly reliable estimates of the percentage distribution of traffic on each. This is true even for the lowest traffic volume system as the only vehicles observed on it were passenger cars, and pickups and panels. The standard error of the percentage for each, assuming a random sample, is quite negligible.

[1] This statement is not applicable to busses, passenger cars and farm trucks, the latter group being composed of all farm vehicles under 22,000 pounds gross weight.

Since seasonal bias was avoided in the ocunts by the application of factors developed from many years of study in the Division of Planning and since counts were available for all rural roads in the state except those carrying very small volumes of traffic, the principal source of error in estimating travel by vehicle type was associated with the separation of city streets into the respective volume systems and the determination of the distribution of traffic, by vehicle type, on those streets. In the spring of 1954, when it became certain that a financial study of highway costs was in the offing, it was decided that more complete information on urban traffic would be required. As a consequence, counts were made in every incorporated city in the state during the summer of that year, and these counts were translated into vehicle mileage totals by tedious computations, street by street, in nearly two-thirds of the cities. It was then discovered that if the cities of over 5000 population were separated into fairly homogeneous groups a high degree of relationship could be found between total vehicle mileage, population, and miles of street. A multiple regression equation was therefore fitted to the data from the cities in each category for which the computations had already been completed; total vehicle mileage was made the dependent variable, miles of street and population the independent variables. The independent variables were not sufficiently correlated to affect the validity of the analysis and the equation derived for mountain and non-mountain, non-suburban cities fitted the data well, i. e., the standard error of estimate was quite small in each case relative to the size of the estimate being made. The equations were then used to complete vehicle mileages for cities in those categories. However, no such relationship was discerned for suburban cities so the calculations for those cities were completed on a street-by-street basis. Percentage distributions of the composition of urban traffic, by city size, were then applied to the vehicle mileage figures on each traffic system to give estimates of urban travel by vehicle type. It was a simple matter to combine these with similar estimates of rural travel in order to obtain a total for each.

Even more difficult than learning the structure of 1954 traffic was the task of projecting it to the program year. Since the finance study staff was committed to using the Automotive Safety Foundation projection of total vehicle mileage, this problem resolved itself into two components: First, apportionment of the A.S.F. total among the eight incremental systems; and, second, determination of the composition of traffic, by vehicle type, on each. It was not reasonable to assume that traffic would increase at the same rate on all roads and streets or that the composition of traffic, by vehicle type, would remain unchanged, either in total or system by system, since all historical evidence indicated otherwise. In addition, the statistical extrapolation of time-series data from the recent past did not seem feasible as there are changing patterns of population growth and per capita income within the state and there exists the definite possibility of legislation affecting the gross weight limit on heavy vehicles. Fortunately, the experience of a neighbor state, Tennessee, was available as a guide in case of the latter happening, and Tennessee counts were in fact used to study the increased incidence of four-axle vehicles which inevitably follows such legislation. Many other issues were similarly settled on an individual basis, with consideration of the circumstances peculiar to each; and, while it is not practicable to discuss them individually, it is certainly proper to say that the final projections were not the result of blindly fitted mathematical curves but were developed by the thoughtful judgment of men who know most about Kentucky traffic and its relationship to the economy of the state.

Determining the proportion of total highway expenditures which are properly chargeable against highway users, system by system, is another major problem which must be faced during the course of every incremental analysis. The usual solution has involved the deduction of non-user contributions and federal-aid from total expenditure requirements, with the remainder accruing to the various classes of highway users. But the determination of the non-user share must necessarily involve some more or less arbitrary procedure, and there remain important questions relative to the correct treatment of federal-aid which have not been settled to the satisfaction of all theorists. The Kentucky staff, therefore, decided to solve the problem by by-passing it. The assumption was advanced that all present-day expenditures on highways are made in order that motor vehicles may use them, and insofar as

highways are intelligently constructed and maintained, all such expenditures are traceable to the number and weight of axle loads which travel over them. The immediate consequence of this assumption is that the pattern of user responsibility can be best established by making an assignment based upon total expenditures. This has the merit of keeping the analysis on a purely technical basis which, in general, relates highway expenditures to the axle loads which occasion them, and thus keeps the concept of responsibility for expenditures separate and distinct from the method of raising and administering the funds.

Except for the variation indicated above, the next steps in the Kentucky analysis were completely conventional. Automotive Safety Foundation expenditure figures for the various incremental systems were allocated among the different registered weights of vehicles on the vasis of their axle load distributions and projected travel, and the expenditure responsibility, by registered weight and vehicle type, was cumulated over all systems to arrive at a total responsibility for each category. The sum of the responsibilities for all registered weights of all vehicle types evidently equalled the proposed annual program expenditure.

At this point, however, the Kentucky study again departed from the established procedure. First, origin and destination studies which included hundreds of thousands of vehicles were used to separate the responsibility in each registered weight category into that attributable to domestic, as opposed to that attributable to foreign vehicles. The per vehicle responsibility for domestic vehicles was then found by simply dividing the total for a given category by the projected registrations in that same category. The foreign vehicle responsibility was left intact and the manner of handling it is still under consideration by the members of the staff who are working on the tax plan and its relationship to the important issues encompassing reciprocity.

The expenditure responsibility determined by the foregoing procedure is evidently not identical with the amount of revenue the state must raise from domestic highway users. As indicated previously, federal-aid and contributions from property owners and other non-users were not even considered in the calculations. But this procedure does establish a structure of per vehicle responsibility by vehicle type and registered weight which depends solely upon the expenditure required by the vehicle's use of the highways, and which can be reduced to a percentage basis and applied to the revenue which the state must obtain from domestic users. For example, if the expenditure responsibility is shown to be $900 for a vehicle in one category as opposed to $300 in another, then the first vehicle has three times the tax responsibility of the second no matter what that tax responsibility may be.

The principal merit of this method, in the opinion of the Kentucky staff, is that it avoids any distortion of tax responsibility which might arise out of the handling of the federal-aid and non-user contributions. An illustration might serve to clarify this point. Suppose that a certain type of vehicle is expected to travel exclusively on the proposed interstate system for which federal-aid provides 90 percent of the funds for construction. If federal-aid is deducted before the incremental assignment of expenditure responsibility is made, then that vehicle is relieved of 90 percent of its tax responsibility for construction expenditures no matter what that responsibility may be. Contrast this with the case of another vehicle type which is expected to travel exclusively on systems which neither federal-aid nor non-user revenues support at all. The tax responsibility relative to construction for the second will be identical with the construction expenditure it occasions, rather than one tenth of it; and, if the axle-load distribution and miles of travel of both types occasion the same construction expenditure, the second will have 10 times the tax bill. This would seem to be a contradiction of the fundamental premise of an incremental assignment which implies that a vehicle's user-tax responsibility varies directly with the expenditure which its use of the highways occasions.

A serious study (*1*) of maintenance costs in Kentucky was undertaken by the Division of Planning early in the spring of 1955. The study was designed to yield estimates of adequate maintenance which could be used, with some modification, by the Automotive Safety Foundation in its program cost projection, and also to provide data for deciding whether there are increments in maintenance attributable to heavy axle loads. More specifically, it was designed to show whether, for roads having given traffic volumes as well as comparable

conditions of age and pavement, higher maintenance costs are associated with higher percentages of heavy axles.

It is necessary to state at the outset that the Division of Planning researchers adhered faithfully to the A.A.S.H.O. definition of maintenance. This definition excludes much work which is not major reconstruction, and for this reason classifications for resurfacing and resurfacing and widening were set up. Indeed, a careful breakdown of expenditure requirements indicated that serious inequities would result if new construction and reconstruction, resurfacing, resurfacing and widening, and maintenance were not all handled separately. The practical importance of separate treatment is emphasized by the fact that the proposed amount of work in each category is quite large and the pattern of incremental responsibility varies widely.

A stratified sampling plan was developed with the bases of stratification being terrain, surface type, and traffic volume. This plan not only provided grounds for apportioning the Automotive Safety Foundation projection of total maintenance costs among the traffic volume systems but also allowed a comparison of maintenance costs on road sections having similar conditions of base and surface, and approximately the same total traffic, but different axle-load distributions. The results of the latter comparison were rather surprising. The standard statistical techniques of simple, partial, and multiple regression were used in an exhaustive attempt to relate maintenance expenditures to axle-load frequency; for given traffic volumes and pavement type, maintenance expenditure per mile was treated as the dependent variable; road age and frequency of heavy axle loads as independent variables. The answer in every attempt was the same: There was simply no evidence, other things being equal, that Kentucky has spent or should have spent more money maintaining roads which carry a high percentage of heavy axles. Indeed, the difference in maintenance expenditures associated with changes in total traffic is not as great as might be expected, as indicated by an average of $1331 for roads carrying 500 to 999 vehicles per day and only $1562 for roads carrying over 3000 vehicles per day.

This result, however, is not as unusual as it might at first appear. The findings do not imply that roads which carry large numbers of heavy axles do not require more repair than those carrying fewer heavy axles, but simply that any such repair is likely to fall into one of the categories of reconstruction. In fact, there is considerable evidence to support the opinion that a Kentucky road which carries large numbers of heavy axles is held with minimum maintenance between relatively frequent major improvements. Be that as it may, the data afforded no empirical basis for an incremental assignment of maintenance costs, and they were charged equally, per mile of travel, against all axles.

REFERENCE

1. MEDLEY, R. D., "Evaluation of Adequate Maintenance Costs in Kentucky from a Probability Sample," Frankfort, Kentucky Department of Highways, 1954.