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Statistical Analysis of a Road Improvement Impact Problem

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Several "standard" research designs are available for the solution of problems. The present discussion illustrates how one of these standard designs, a regression design, was applied to a highway impact study. 1/ In the case in point each observation in the data set consisted of a property value matched with measures of the road service of the subject property and other qualities of the property bearing on its value (for example, land utilization). The measurements of road service were in miles of road for a cross classification of road surface type by road use type (e. g., we could speak of 10 miles of dirt road used for the journey to work).

The first problem was to estimate the association of property value with road service.

THE ESTIMATES

The problem was handled by multiple regression methods using inverted matrices. This method is not new, but the large amount of computational labor involved has discouraged its use on as an extensive a scale as that in these studies. However, the use of electronic high-speed computers made the inverted matrix solutions practicable here. The use of inverted matrices simplified the calculation of errors of the regression coefficients, the tests for significant differences among the coefficients, and the deletion of independent variables from the regressions in order to simplify the presentation and use of the findings of the studies.

In general, the postulated relationships took the form:

$$Y = \alpha + \sum_{i=L}^{n} \beta_i X_i + \epsilon$$

in which Y is property value, α is a constant, and the X_i's are the variables of road use, etc.

For each study, the data were arrayed on punch cards and matrix transposition, multiplication, and inversion steps yielded the net regression coefficients (the b_i's as estimates of the β_i's), the variance-covariance matrix, and the error variance.

Decision Criteria

These materials were then used to resolve each regression into its principal components. Terms were deleted using t criteria for the hypotheses $\beta_i = 0$ and $\beta_i = \beta_j$ and on the basis of the contribution of each

1/See William L. Garrison, "The Benefits of Rural Roads to Rural Property", Seattle: Washington State Council for Highway Research, Part IV of the Allocation of Road and Street Costs, 1956.

deleted term to the error variance. This deletion process decreased the quality of each estimating equation. On the other hand, each full regression equation contained eleven or twelve terms and in many of the studies a number of the terms had little effect on the error variance. In addition, the large number of terms in each study limited the potential uses of the measurements in practical applications.

Criterion of the size of the error variance was also used to select among the estimating equations utilized in the studies. Measurements of amount of road were made in two ways—a simple measurement and a weighted distance measurement (miles traveled per unit of time). In each study area the regression (or regressions) using the weighted measurements gave a lower error variance than the regression using simple distance measurements and in nearly all cases the simple measurements were discarded.

In addition, criterion of the size of the error variance was used in two studies to select the "best" functional relationship between weighted distance measurements and property values. Theoretical considerations suggested that property values would vary with the inverse of distance. 2/ Regressions using this function were compared with linear functions and the "best" function was taken to be that with the least error variance. Of course, this procedure did not yield a known "best" function. The procedure allowed the selection of the "best" function of the functions considered.

The regression coefficients were of two types. Some of the coefficients related to dichotomized observations of land utilization and the like. In these cases the hypothesis tested took the form $\beta_i = 0$ and were rejected in almost every instance. The remainder of the coefficients related to the distance measurements. In these cases we were interested first in the hypothesis $\beta_i = 0$. For one of the trip types (amenity travel) this hypothesis was not rejected in almost every case. For the remaining trip types the hypothesis was not rejected for the paved road terms in about half the cases. Next, for the trip types where the hypothesis $\beta_i = 0$ was rejected for poorer than paved roads, the hypothesis $\beta_i = \beta_j$ was tested to compare the paved road coefficients with the non-paved road coefficients. This hypothesis was rejected for the paired coefficients in at least one of the trip types in every study.

THE IMPACT

Once the association of property values with road service was known it was a simple matter to estimate the impact of road improvements. One item of information, for example, was that travel via gravel roads for usual household shopping in one farm situation depreciated farm property values by approximately one-fifth of a cent, per acre, per mile traveled, per year. Travel of one thousand miles in a year would depreciate each acre of farmland by two dollars and fifty cents. To find the impact of road improvement all that needed to be done, then, was remove the depreciation of value by present service roads. In the example case and if the gravel road was improved to a paved road, the depreciation of two dollars and fifty cents would be removed and replaced by the lesser

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2/Based on the observation that costs of transfer are concave downward over distance (see Edgar M. Hoover, "The Location of Economic Activity" New York: McGraw-Hill, 1948, pp. 19-21.)

depreciation of a paved road. The impact is taken to be the difference between the two rates of depreciation.

But will this procedure yield valid measures of impact? The derived measures of property value depreciation apply only if stable patterns of road utilization can be assumed. Put another way, it is necessary to know if the structure generating observed values will change when roads are improved. 3/

This question posed the second problem for statistical analysis. It was desired to know if propensity to travel for any purpose varied from road surface type to road surface type.

VERIFICATION OF THE MODEL

The model for this portion of the research was also a regression model. Trip frequency was compared with road surface type in light of (1) different types of trips that may be made and (2) a presumed tendency for trip frequency to diminute with length of trip in a non-linear manner. The latter occasioned the transportation of the model to logarithms. Differences in road type were introduced into the calculations by using a separate term in the regression for each type of road. This gave the postulated relationship:

$$\log F = \alpha + \sum_{i=1}^{n} \beta_i \ (\log X_i + 1) + \epsilon$$

in which F = trip frequency (trips per week); α = a constant term; X_1 = distance via paved roads to the usual terminus of a trip type (distance in miles); X_2 = distance via gravel roads; X_3 = distance via dirt roads; and β_i = the parameters to be estimated. The problem to be solved is a compromise. The postulated relationship attempts to recognize both the presumed tendency of trip frequency to diminute with increased distance and the presumed tendency for trip frequency to vary with the type of road over which the trip is taken. A separate model was used for each type of trip (for example, the journey to work).

The results of calculations using this model tended to verify measures developed with the regression model discussed earlier. In general, relationships could not be developed in the form specified. This is an indirect sort of verification, of course, but it does illustrate another place where regression was found useful in a road impact study.

Obtaining Data for a Highway Impact Study

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How do highway improvements affect areas? The answer to this question obviously depends on a number of considerations. Thus it is not surprising that research designs addressed to the question incorporate a variety of data and data gathering techniques.

Steps used in obtaining data for a recent study in Washington State

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3/Put still another way, it was desired to know if the model could be considered to be a "uniequational complete model."