INFLUENCE OF SIZE AND ADMINISTRATIVE ORGANIZATION ON COSTS OF RURAL ROADS*

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INTRODUCTION

Providing and maintaining roads are major public services. Costs of these services are influenced by many factors. This paper examines the influence of two factors, size of operation and type of administrative organization, on costs of rural roads.

An administrative unit providing roads for a small area, county, or township, with a given density of roads might experience higher costs per unit of area than an administrative unit providing road service for a larger area, all other conditions being the same. It likely would experience disadvantages in buying supplies and equipment, making full use of equipment, hiring competent help, and in other ways. However, the unit with a large area could run into diseconomies through high administrative and supervisional costs. Actually, it may not be that simple. This study tests the idea empirically.

Factors other than costs influence decisions made by counties (and townships) to enlarge their operations. Consolidation of counties or consolidation of the function of providing roads (by removing that function from the auspices of township government) is possible, though subject to problems. The study reported herein is limited to an analysis of costs as affected by size of operation and administrative organization.

Each county in Kansas is divided into a set of townships with some counties having as few as three townships while others are divided into more than 30. In approximately 60 percent of the counties within Kansas, the individual townships have no function to play in providing for local rural roads. These counties are known as county unit counties, which provide for the county to finance (local), build, and maintain all rural roads. The noncounty unit counties provide for townships to individually finance (local), build, and maintain rural roads except primary roads for which the county is responsible.

Size of operation usually is measured in terms of output. The use of miles of roads as the output was not used in this study as might be expected. That would have involved combining roads of different kinds and qualities to obtain a "quantity of roads." Instead, the square miles of area were used with densities (miles) of kinds of roads considered as one of the independent variables affecting costs of roads.

Two counties with the same number of square miles could be viewed as having the same output only if other factors affecting costs, such as densities of types of roads, traffic flow, topography, wealth, and others, were at the same level. Yet this is rarely the case. A procedure is needed whereby the separate effect of size of operation can be determined. Multiple regression was used to study the effects of one variable (size of output) by allowing the removal of the effects of other significant variables. Various regression models were tested separately for the two groups of counties, and then a regression model was tested for all counties taken together, with a dummy variable added to distinguish county from noncounty units. Costs and other factors for noncounty units (counties and townships responsible for roads) were totaled for the county and townships so that county and noncounty units could be compared. To avoid peculiar cost conditions for any one year, averages for 1965, 1966, and 1967 were used. This study analyzed costs for 59 county units and 41 noncounty units in

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Except for the variable square miles, all independent variables were expressed as deviations from their respective means. Miles of earth road (E), for example, were expressed as $E - \bar{E}$, with $\bar{E}$ being the mean mileage of earth road per square mile for the counties included in the analysis. This was done so that when the independent variables other than square miles of area were at their mean value, they would be equal to zero, forcing the costs to accrue to the square miles of area. Thus, the independent variable, square miles of area, that was used as a measurement of output may be defined as a square mile of area with average densities of all other variables considered. This facilitated the estimation of the average cost equation.

The average cost equations obtained in this study show the relationship between size of operation of the counties and costs for the three-year period. To consider the average cost equations as long-run cost functions assumes that each county was operating near (short-run curve tangent to long-run curve) its lowest average costs. It is more realistic to consider the curves developed as average experience curves. Individuals making decisions about alternative systems probably would be more concerned with "average experience" curves than an "optimal" experience. Regardless, maxima and/or minima average costs likely would have occurred at the same (or nearly the same) output, but at higher or lower levels than an equation based on cost of counties with the lowest average costs within a given size [1]. An alternative, not used in this study, would be the development of a long-run average cost equation by the formulation of an envelope curve just tangent to all possible short-run average cost curves. That would have required a number of counties with the same size of plant but operating at different levels of output. Such data were not available.

Size of county varied from 150 to 1,443 square miles, paved rural roads from zero to 469 miles, gravel rural roads from 12 to 1,388 miles, assessed valuation of property from $10 million to $653 million, and other factors varied widely. If two or more "independent" variables are closely related linearly, multicollinearity exists, causing coefficients in themselves to be meaningless. One solution is to construct new variables that are linear functions of the original variables, are independent of one another, and account for as much of the variance of the original variables as is possible with a minimum number of new or constructed variables [4]. The technique of formulation of new variables by the use of principal components accomplishes that goal. The principal component is then included with its values in the equation like any other variable [2].

NONCOUNTY UNITS

We used a regression program with X (square miles in county) and X^2 as independent variables, and then one with X^3 and $X^{3.5}$ included.[1] Using stepwise regression, both programs produced identical results for the noncounty units; that is, the last significant variable added in both runs produced the same regression equation. The inclusion off X^3 and $X^{3.5}$ insured that the equation had as much flexibility as the data warranted. Stepwise regression was used so that superfluous variables could be identified and discarded. The equation was:

$$(1)\ \hat{Y} = 332{,}847 + .556X^2 + 359{,}722E + 771{,}279G + 481{,}318P + 5.63D^2 - .0028D^3$$

where

t values are 6.84, 2.02, 4.62, 1.49, 9.50, and -9.92;

Goodness of Fit, $F(6, 34) = 40.55$;

R^2 = .88;
Y = total cost;
X = square miles of area in the county;
E = miles of earth road per square mile expressed as a deviation from its mean;
G = miles of gravel roads per square mile expressed as a deviation from its mean;
P = miles of paved roads per square mile expressed as a deviation from its mean, and
D = a measurement of wealth, vehicle registration, and population expressed as a deviation from its mean[2].

The coefficients of the independent variables appear to have the right signs (+ or -). Size of coefficients for the three kinds of roads appear large. The variable is miles per square mile, and in most counties only a fraction of a mile of a given kind of road per square mile existed. So to increase the

[1] Some functions do not permit minima and/or maxima even if the data warrant them. See [5, 3].

[2] D^2 is an expression of $D^2 - \bar{D}^2$, and D^3 is an expression of $D^3 - \bar{D}^3$. When D^2 and D^3 are at their mean values they are equal to zero.

density of roads by one unit per square mile would cause an extremely large increase in cost. For this study, however, the coefficient for the size factor is of prime importance; other coefficients are useful in estimating Y.

If mean values for earth, gravel, paved roads, and factors other than size of output are assumed, the total cost estimating equation would be:

(2) $Y = 332,847 + .556X^2$.

The derived average cost function is:

(3) $AC = 332,847/X + .556X$

and is U-shaped (Figure la).

Any number of average cost (per square mile) curves can be drawn with assumed values for other variables in the total cost function. If factors E, G, P, and D are not related to X, the average cost curve will be either higher or lower than when mean values are assumed.[3] The average cost curve for assumed means for E, G, P, and D is used to indicate the influence of size on average costs within the administrative arrangement.

The average cost depended on two parameters: the value of the intercept and the coefficient of X^2 (in the total cost equation).

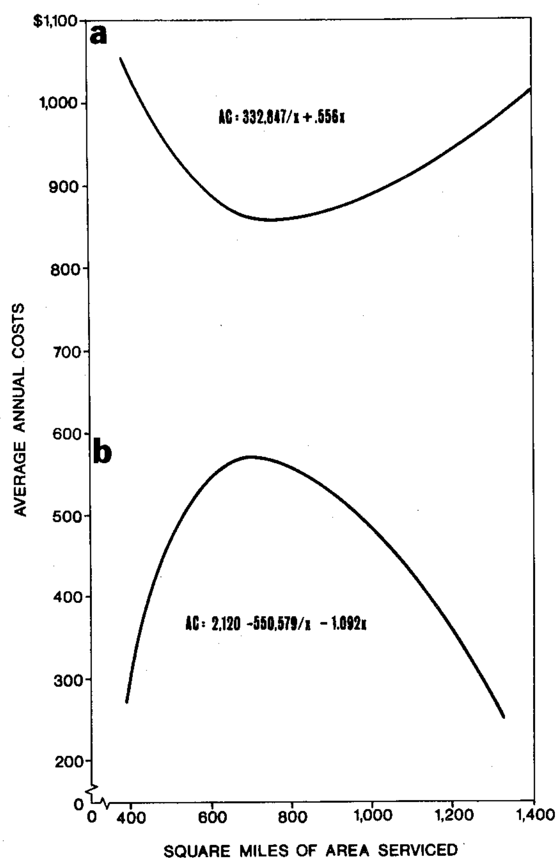

Figure 1. AVERAGE COST OF PROVIDING RURAL ROAD SERVICE FOR:

a. Noncounty units and
b. County units

COUNTY UNITS

An identical process was followed with county units. The stepwise regression program with X and X^2 produced:

$$(4)\ \hat{Y} = -550,579 + 2,120X - 1.092X^2 + 147,412E + 242,540G - 2,522Q + 10,929R + 5,046D.$$

where

t values are 6.21, 5.27, 2.77, 6.27, 3.97, 2.37, and 10.23;

Goodness of Fit, $F(7, 51) = 43.98$, and

$R^2 = .86$

where Q was a measurement of the quality of road service, and R was a measurement of precipitation. The derived average cost equation is:

(5) $AC = 2,120 - 550,579/X - 1.092X$ (Figure lb).

Regression coefficients of the various powers of X and the intercept itself, as they appear in the average cost curve, should not be viewed separately. As a unit they define the average cost curve in the relevant range of data.

Adding X^3 and $X^{3.5}$ changed the shape of the average cost curve little. The sign for quality of road service (Q) is unexpectedly negative. A good explanation is not apparent. The measurement of quality is small, so the effects on total cost are not large. Again, the emphasis in this study is on size of operation.

NONCOUNTY AND COUNTY UNIT COSTS COMPARED

We have found the usual U-shaped cost curve for the noncounty units. However, the curve is inverted for county units. The curves do not intercept when county averages of independent variables (except size) are assumed for each of the two sets of counties. If other values are assigned to the independent variables, the two curves might intercept, at least near

[3] A low level of correlation may occur without seriously affecting minima and/or maxima in relation to size of county.

the mean size county.

A regression was programmed using the full set of observations of 59 county units and 41 noncounty units. A dummy variable was added, taking the value of one when the administrative structure was a noncounty unit, and zero when the county unit structure was used. The value of the coefficient was $81,031, indicating that total costs increase if the noncounty unit administrative structure is used.

Simple averages of costs for groups of county and noncounty units would give different results because of differences in size and characteristics of the two groups of counties. It is necessary, therefore, to use a multiple regression technique to estimate the separate effects of one factor while other factors are held constant.

CONCLUSIONS

Applying models permitting maxima (peaks) or minima (valleys) average costs to noncounty road units in Kansas showed average costs decreasing as size of output increased from 150 to approximately 800 square miles. From that point, average costs increased, indicating that the optimal size of county was approximately 800 square miles.

The influence of size of output on average costs for county units was essentially opposite from noncounty units. Apparently, small county units were able to provide roads at lower costs than those somewhat larger which incurred expenditures for equipment, materials, and labor out of proportion to the increase in roads to be provided and maintained. Beyond approximately 800 square miles, substantial economies were found up to at least 1,400 square miles.

Through regression analysis, total costs were estimated to be approximately $81,000 more for noncounty than for county units. One can conclude that road service can be provided at a lower cost by the county unit than by the noncounty unit system. In addition, significant economies can be gained by the larger counties with the county unit system.

Decisions to enlarge the operating unit or to change the administrative organization are influenced by factors other than costs. Opportunities to change may be quite restrictive for political and other reasons. Careful study of each county is necessary.

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