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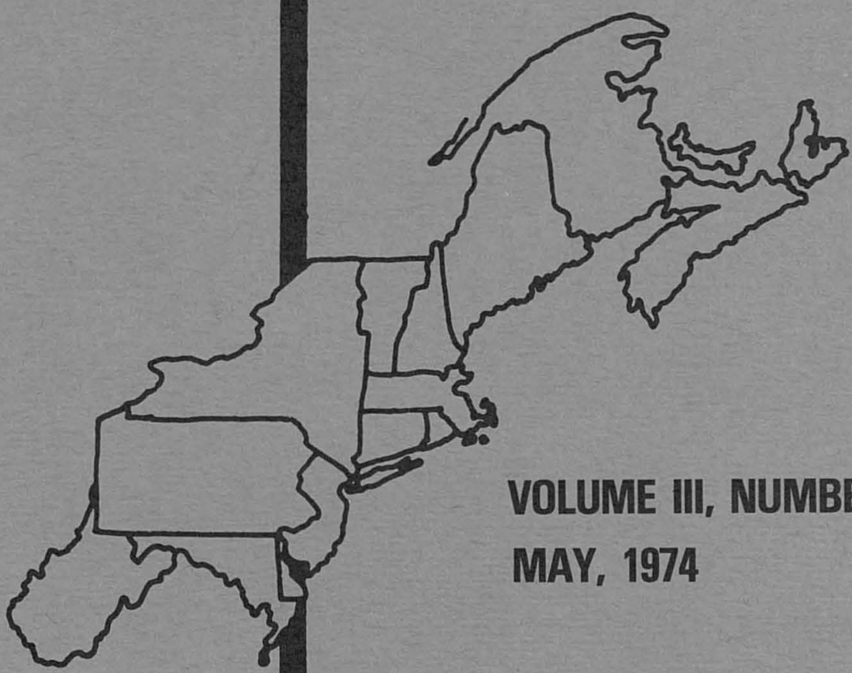

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ECONOMIES OF SIZE IN HIGHWAY MAINTENANCE AND ADMINISTRATION: A PRELIMINARY ANALYSIS FOR THE COUNTIES OF NEW YORK STATE*

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Introduction

"Give the government back to the people," a popular phrase in recent months, exemplifies the concern over the proper role of the federal, state and local units of government in providing and financing public services. Constituents are frustrated by bureaucratic programs, frequently insensitive to local needs, that are initiated at higher levels of government. They are equally frustrated by the inability of units of local government to initiate and finance programs designed to satisfy the needs of the local community.

Local government leaders attempting to provide an adequate quantity and quality of public services face a dilemma. During the past decade, the demand for local services has been growing more rapidly than revenues derived from local sources, thus creating a "revenue gap." The revenue gap may be partially explained by the heavy reliance of units of local government on the property tax for locally generated revenue.1/ Growth in the property tax base during the 1961-71 period, as measured by changes in the assessed value of fully taxable real property, amounted to about 40 percent for the counties in New York State. Property tax revenues grew by about 141 percent during the same period [5, p. 16]. However, a more important reason for the revenue gap is the tremendous growth in local government expenditures. During the 1961-71 period, total general purpose expenditures of the counties of New York State increased by over 300 percent, from $513.2 million to $2.1 billion [5, p. 28]. Increased costs of providing social services programs, public safety and highways contributed substantially to the increase in county expenditures.

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* Helpful comments were received from E. A. Lutz, W. G. Tomek, and the reviewers of this Journal. The authors are responsible for remaining errors or omissions.

1/ In 1971, property tax revenues represented slightly more than 76 percent of local government tax collections in New York State.

Highway expenditures have declined in relative importance during the past decade, however they maintain a prominent position in local expenditure decisions. For the counties of New York State, highway expenditures increased from $69.3 million to $110 million, a 58.7 percent rise, during the 1961-71 period.2/ Highway expenditures in the towns, counties, and villages amounted to over $305 million in 1971, the latest year for which figures are available.

The widening gap between expenditures and locally generated revenues has been filled in large part by state and federal aid to local governments. During the 1961-71 period, state and federal aid at the county level increased from $193 million to $917.1 million, a 375 percent rise.3/ Greater state and federal aid have been accompanied by greater state and federal involvement in local affairs, and have further complicated the struggle of local leaders for continued "local control." An additional effect of the revenue gap has been to heighten pressure on local government leaders to cut costs by reducing or eliminating inefficiencies in the provision of local services.

Over the years, few services have been subject to as much criticism for overlap, duplication and inefficiency as highway administration and maintenance. The complex of state, county, town and village highway departments with overlapping jurisdictions is often viewed as prima facie evidence of inefficiency resulting from duplication of men, machinery and effort.4/ Critics often suggest that highway departments be reorganized to eliminate small, inefficient units. Their road mileage would be taken over by larger, more efficient units. The result would be substantial reductions in per unit costs resulting from economies of size achieved through the reorganization. However, research designed to analyze economies of size in the provision of public services at the local level has been scattered and inconclusive.

2/ During the same period, highway expenditures by the towns of New York State increased from $76 million to $160 million, an increase of almost 109 percent. Highway expenditures remain the single most important budget item at the town level. Village highway expenditures increased from $22 million to $35 million during the 1961-71 period. Highway expenditures remain the second most important budget item at the village level.

3/ State aid to the counties of New York State increased from $130.6 million to $527.8 million (304 percent), and federal aid increased from $62.4 million to $489.3 million (684 percent) [5, p. 16].

4/ The State of New York is divided into 10 multi-county highway districts, each containing a regional office through which the State maintains its highways. Each county has either a highway or public works department. The entire area of each county is divided into a number of towns, each with its own highway department. In addition, many towns contain incorporated villages which usually have a highway or public works department. Thus, the jurisdictions of state, county, town and village highway departments frequently overlap.

The purpose of this study is to provide a preliminary analysis of the cost of providing highway services, including maintenance, snow removal and administration, at the county level in New York State. The analysis focuses on economies of size in providing highway services. It is, by necessity, efficiency oriented. Although decisions are seldom made strictly on the basis of efficiency, it is felt that this type of analysis will provide information useful to local policy makers as one input in the decision process.

Methodology

Previous Studies

The three methods most often proposed for estimating economies of size and developing long-run average cost curves are the survivorship technique, the synthetic approach and the direct approach.

Using the survivorship approach, the optimum firm size is determined by classifying the firms in an industry by size and calculating the share of industry output coming from each class. If the share of a given class falls over time, that class is relatively inefficient and, in general, the more rapidly the share falls the more inefficient the class [9, pp. 54-71]. The survivorship approach has been used to estimate long-run average cost curves under the assumption of pure competition. This approach is not realistic for analyzing economies of size for highway units which operate as political rather than purely competitive entities.

The synthetic firm approach involves developing short-run and long-run average cost curves on the basis of economic-engineering data. Hypothetical firms are developed over a range of feasible capacity alternatives [2, p. 29]. For each size of plant, the short-run average cost curve is approximated by varying the level of output. By assuming alternative levels of fixed resources and varying levels of output, short-run average cost curves are developed for various plant sizes. The long-run average cost curve is developed as an envelope curve based on the short-run curves. This method eliminates the influence of variables other than size on cost because the cost data are synthesized on the basis of theoretical plant sizes with varying levels of fixed resources. This approach, however, is difficult to apply in a study of highway costs for several reasons. First, a highway department "produces" a number of outputs, including maintenance and repairs, snow removal, sanding and salting, etc. Second, determination of technical coefficients for a number of different sizes and types of highway equipment would be quite difficult. Thus, the synthetic approach has a number of practical limitations that make it difficult to apply to the study of highway units.

The direct approach of estimating average cost curves requires aggregate data for firms of various sizes and levels of output. A single average cost position is derived for each unit, assuming that it is operating at its most efficient level [1, p. 77]. Regression analysis is then utilized to establish the relationship between cost and size of unit. The direct approach, or some variation of the direct approach, has been used extensively despite problems with eliminating the influence of variables other than size upon average costs.

The direct approach was utilized by Swanson in an analysis of highway administrative units in Illinois [10, 11]. Separate linear regression models were estimated for highway administration and highway maintenance. Mileages of various types of road and assessed property valuation for each administrative unit were independent variables in total cost equations, from which average cost curves were derived. Swanson's results indicated a pattern of decreasing costs per mile as size of administrative units increased. However, costs per mile decreased at a decreasing rate. Swanson stops short of drawing inferences regarding the cost reductions resulting from consolidation into county units. He indicates, however, that expected savings appear to be substantial enough to warrent consideration of action to merge at least a few of the very small units into larger units [11, p. 31].

The direct approach was also used by Lamb in a study of county versus township road systems in Kansas [1]. Highway expenditure data were obtained from county and township budgets and a single outlay or cost figure was developed for each highway unit. Total cost curves then were estimated for county and township units. Total cost was hypothesized to be a function of the number of square miles of area administered by the unit, the number of square miles squared, property valuation, motor vehicle registration, population density, the density of various types of roads, inches of rainfall, inches of snow, number of days with snow on the ground, the quality of roads and bridges, and smoothness of topography.[5] Except for the costs and square miles of area serviced, all variables were measured as deviations from their means. Thus, when the mean value of each of these independent variables was multiplied by the corresponding regression coefficient, all variables dropped out of the equation except those related to road mileage. Average cost curves were then found by dividing the total cost equation by the square miles of road services.

Average costs for the county units were found to increase up to approximately 700 square miles of area and decline to a minimum of about $275 per square mile at 1,300 square miles of area. Average cost curves

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5/ Multicollinearity among property valuation, motor vehicle registration and population density was quite high. Thus, principle component analysis was used to develop three principle components combining the influence of these three variables. One principle component explained such a large proportion of the variation that the remaining two components were dropped from the analysis. Similarly, principle component analysis was used to develop principle components from the three precipitation variables -- inches of rainfall, inches of snow and number of days with snow on the ground. All three of the principle components were used in the analysis [1, pp. 104-107].

developed for the town highway units were either horizontal or increased throughout their lengths, thus indicating that these units did not achieve economies of size as firm size increased. Lamb concludes that there are economies to be achieved if rural road services are directed by the single administrative system of the county unit.

Preliminary Analysis for New York State

The direct approach was also used in this study of county highway departments in New York State. Highway budget and/or expenditure data for 1970 were obtained for 56 of the 57 upstate counties.6/ Expenditures were generally reported in six different categories, including traffic, administration, engineering, maintenance, snow removal and snow-removal-state.7/ Expenditures classified in the administrative category include the salary of the county highway superintendent, his secretarial staff and related expenses. Engineering costs are primarily administrative, often including the salary of the assistant superintendent, who is also the engineer.8/ Maintenance expenditures include those costs of labor, materials and machinery associated with road repair, resurfacing and other maintenance activities. Maintenance expenditures represent the largest single item among the expenditure categories. Snow removal expenditures include the cost of labor, sand, salt and other materials, and the cost of machinery associated with removing snow and ice from county roads.9/

6/ Highway expenditures for 1970 were not available in published form for a number of counties. A questionnaire was mailed to clerks of County Legislative Boards in those counties for which published data were not available. By combining County Legislative Proceedings and mail questionnaires, 1970 expenditure data were obtained for 47 counties. Budget data, rather than actual expenditures, were utilized for nine additional counties. One county was eliminated from the study because neither expenditure nor budget data could be obtained.

7/ The expenditure category "snow-removal-state" was not included in the analysis because the county is reimbursed by the state for all snow and ice removal performed on state roads.

8/ Engineering costs represent a relatively small proportion of total highway expenditures. In recent years, very little new road construction has been undertaken at the county level. Thus, engineering costs are low relative to maintenance costs.

9/ The costs of machinery for snow removal as well as for maintenance, were determined at the county level by multiplying the total number of hours each piece of equipment was used in various operations by predetermined hourly rates established by the State. Revenues generated through the use of machinery rental rates go into the County Road Machinery Fund, and are subsequently used to purchase additional equipment.

For this analysis, expenditures for traffic, administration, engineering, maintenance and snow removal were aggregated into three cost categories for each county - maintenance, administration, and snow removal.10/ The maintenance category includes both traffic and maintenance, while the administration category contains the sum of administration and engineering costs. These cost categories were used to establish the relationship between cost of highway services and size of administrative unit.

Analysis and Results

The models developed in this study are designed to clarify the relationship between the cost of providing highway services and the size of the administrative unit. First, a model is formulated which contains those variables thought to explain variations in total highway expenditures, including the cost of administration, maintenance and snow removal. Then, to further isolate the relationship between costs and size of unit, cost equations are developed separately for the maintenance, administration and snow removal functions.

Highway Maintenance, Snow Removal and Administration

The regression model formulated to explain variations in total highway costs is presented in equation (1).

$$(1)\quad Y_t = a + b_1\,RM + b_2\,RM^2 + b_3\,P + b_4\,S_1 + b_5\,S_2 + b_6\,S_3 +$$

$$b_7\,MV + b_8\,PD + b_9\,FV + b_{10}\,CB + b_{11}\,Q + b_{12}\,T + b_{13}\,DV$$

A summary of the dependent and independent variables used in this analysis is presented in Table 1. The parameters of this model were estimated using multiple linear regression. The adjusted $R^2=.99$, however, the existence of multicollinearity among several sets of variables reduced the precision of the estimated parameters of the separate effects. A number of additional regression models containing various combinations of independent variables were hypothesized, and the parameters of those models estimated. Only road mileage, the number of county bridges and motor vehicle density were found to significantly affect total highway costs.

10/ Employee benefits, including state retirement, social security, workman's compensation, and hospital and medical insurance, were excluded from the analysis. These expenses were generally reported as a lump sum rather than being allocated across expenditure categories.

Table 1
Dependent and Independent Variables Used in Regression Equations to Explain Variations in Highway Costs

Symbol	Explanation of Variable
CB	= number of bridges maintained by the county highway department a/
DV	= dummy variable, 1 if the county has a public works department, 0 otherwise
FV	= full value of real property per capita b/
MV	= motor vehicle registrations per square mile of land area c/
P	= annual precipitation in inches d/
PD	= population per square mile of land area c/
Q	= quality index of county roads equal to the percentage of county road mileage rated "fair," "poor" and "impassible" e/
RM	= road mileage administered by the county highway department a/
RM^2	= road mileage squared a/
S_1	= annual snowfall in inches d/
S_2	= number of days with two or more inches of snowfall d/
S_3	= number of days with five or more inches of snow cover on the ground d/
T	= topographic index for county roads equal to the percentage of county mileage classified as "rolling", "hilly" and "mountainous" f/
Y_a	= total cost of administration
Y_m	= total cost of providing maintenance
Y_s	= total cost of providing snow and ice removal
Y_t	= total cost of providing highway administration, maintenance and snow removal

a/ Compiled from data contained in the New York State Department of Transportation's publication "Local Highway System - County" [7] and "Local Bridge System - County" [6].

b/ Obtained for 1970 from the Report on Municipal Affairs of the New York State Department of Audit and Control [4].

c/ Obtained from the 1972 New York State Statistical Yearbook [8].

d/ Weather data were collected for one weather station in each county from the U.S. Weather Service Office at Cornell University.

e/ The New York State Department of Transportation has rated the adequacy of each section of county road in the state either "good", "fair", "poor" or "impassible" [7]. The quality index was developed for each county by subtracting from total road mileage the mileage of roads rated "good" and dividing by total road mileage.

f/ The New York State Department of Transportation has classified each segment of county roads as "flat", "rolling", "hilly" or "mountainous" [7]. The topographic index was developed by subtracting from total county roads the miles of road classified as "flat" and dividing the remainder by total county road mileage.

None of the precipitation variables were found to bear a significant relationship to total highway costs.11/ In addition, the explanatory power of both the quality index and the topographic index was disappointing. It was hypothesized that counties with larger percentages of low quality roads would experience higher total highway costs. However, this analysis found no consistent relationship between quality of road and total highway costs.12/ It was also hypothesized that increases in the topographic index would also be associated with increases in total county highway costs. However, no consistent relationship was found between the topographic index and highway costs.

As previously stated, the only variables found to have a statistically significant impact on total highway costs were road mileage, the number of county bridges maintained by the county highway department, and motor vehicle registrations per square mile of land area. Each of these variables was hypothesized to bear a positive relationship to total highway costs. Total highway costs were expected to increase with size of administrative unit. Similarly, the relatively costly nature of bridge repairs led to the expectation that total highway costs rise with bridge numbers. Finally, to the extent that more vehicles per square mile implies greater road use, a positive relationship was expected between total highway costs and vehicle density.13/

The final regression equation relating total highway costs to road mileage, county bridges and vehicle density is presented in (2).

$$(2) \quad Y_t = \underset{(-3.84)}{-457{,}550} + \underset{(8.90)}{2{,}876.60RM} + \underset{(3.49)}{3{,}504.70CB} + \underset{(22.16)}{3{,}165\ MV}$$

11/ Annual precipitation was, however, found to have a significant impact on the cost of providing snow removal. This relationship is discussed in a subsequent section.

12/ At least a portion of this phenomenon may be attributed to the quality index and the Department of Transportation's system of rating highway adequacy. Over 90 percent of all county roads in New York are rated "good". Variation in the percentage rated "good" from county to county is quite small. Thus, the quality index is based on data that may not reflect adequately the differences in road quality across the state.

13/ The simple correlation coefficients between population per square mile and motor vehicle registrations per square mile; population per square mile and full value of real property per capita; and, motor vehicle registrations per square mile and full value of real property per capita are all greater than .90. The more heavily populated areas tend to have a greater concentration of motor vehicles, higher full value of real property and, in addition, spend greater amounts for highway administration, maintenance and snow removal than the sparsely populated areas.

The adjusted R^2=.94. Numbers in parentheses are t-values. All variables are statistically significant at the 99 percent level. The regression coefficients may be interpreted in the usual manner. For each additional mile of county highway administered and maintained, total highway costs increase by $2,876.60. For each additional bridge maintained by the county highway department, total highway costs increase by $3,504.70. For each additional motor vehicle per square mile, total highway costs increase by $3,165.

An average cost curve may be derived from (2).[14/] The regression coefficients for CB and MV are multiplied by their respective mean values and the product is added to the constant term. Thus,

$$(3) \quad Y_t = \hat{b}_o + \hat{b}_1 RM + \hat{b}_2 \overline{CB} + \hat{b}_3 \overline{MV}$$

Mean values $\overline{CB}$ (101.41) and $\overline{MV}$ (159.15) are substituted into (3) to get:

$$(4) \quad Y_t = -457{,}550 + 2{,}876.60RM + 3{,}504.70\ (101.41) + 3{,}165\ (159.15)$$

$$(5) \quad Y_t = 405{,}222.10 + 2{,}876.60RM$$

Next, (5) is divided by road mileage to get cost per mile.

$$(6) \quad LAC_t = Y_t/RM = 405{,}220.10/RM + 2{,}876.60$$

The long-run average cost curve presented in (6) was plotted over county road mileages in New York State ranging from 90 to 1,190 miles and the resulting average cost figures are presented in Table 2.[15/] Highway costs per mile decline rapidly up to about 400 miles of county roads. For highway units with more than 400 miles of county roads, costs per mile decline more slowly. The shape of the long-run average cost curve is apparent in Figure 1. It slopes downward to the right over the entire range of county road mileage.

14/ The decision to estimate the total cost curves and then transform them into average cost curves was based primarily on computational convenience. The average cost curves may also be estimated directly.

15/ Cost curves derived through regression analysis differs slightly from the long-run average cost curve of economic theory. Highway departments are political units operating with a given amount of funds. They attempt to maximize the supply of road service rather than producing a given output at the minimum cost. Thus, points on the regression curve lie slightly above points on the theoretical long-run average cost curve. It may be more accurate to refer to the regression curve as the typical long-run average cost curve [1, p. 89] or the average experience curve [3, p. 321].

Figure 1
Average Total Cost Per Mile of County Road

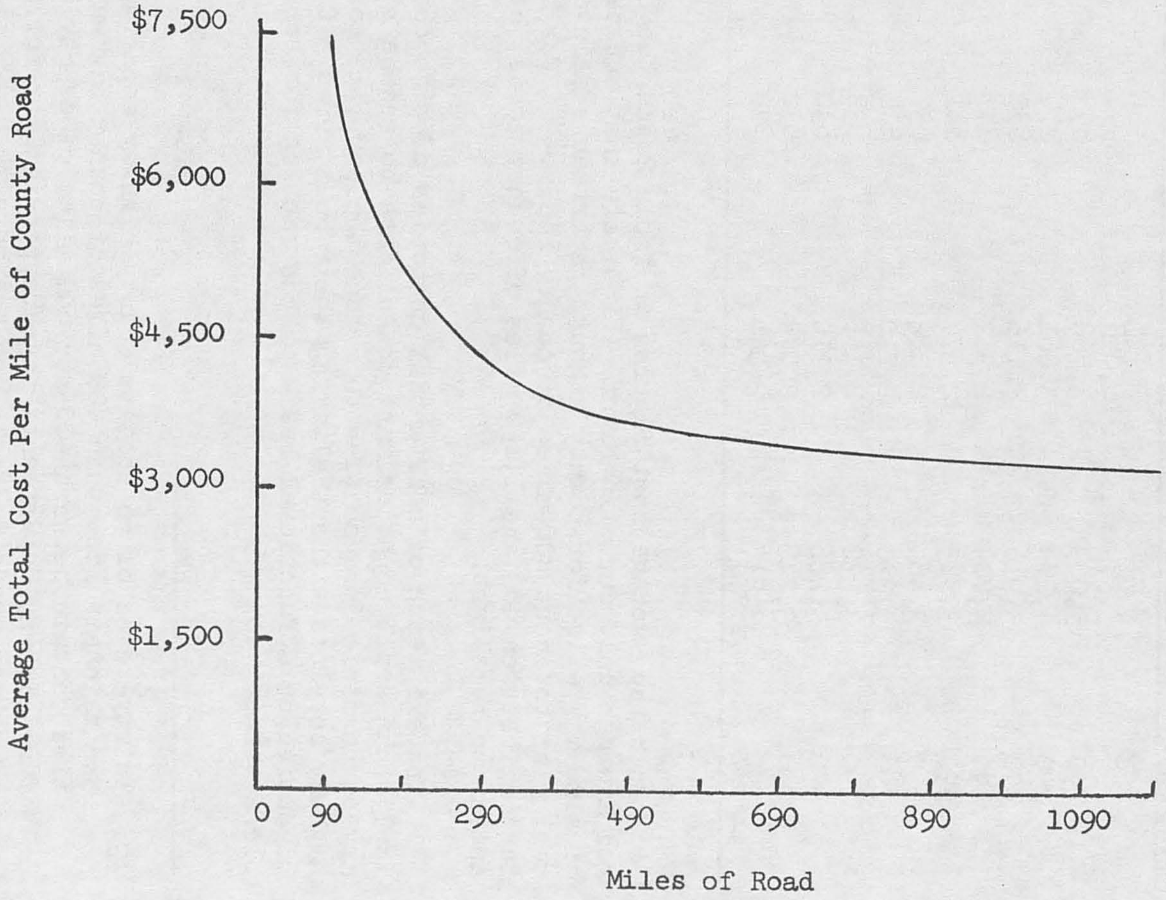


Table 2
Regression Estimates of the Average Cost of
Providing Various Highway Functions for
Specified Road Mileages

County Road Mileage	Average Total Costs	Average Maintenance Costs	Average Snow Removal Costs	Average Administrative Costs
90	$7,379	$6,048	$990	$1,586
190	5,009	3,768	898	568
290	4,274	3,061	870	312
390	3,916	2,716	855	231
490	3,704	2,512	847	219
590	3,563	2,377	841	240
690	3,464	2,282	837	280
790	3,390	2,210	834	332
890	3,332	2,155	832	392
990	3,286	2,110	830	457
1,090	3,248	2,074	830	526
1,190	3,217	2,044	828	598

Both the average cost figures in Table 2 and the corresponding long-run average cost curve in Figure 1 indicate that substantial economies of size may exist for county highway departments maintaining and administering up to about 400 miles of county roads.16/ For highway units maintaining between 400 and 1,190 miles of county roads, economies of size appear to be slight.17/

The existence of substantial economies of size does not necessarily imply that small counties must consolidate to reduce highway costs. It may be possible for counties to reduce the per mile cost of providing highway services without altering their boundaries. Either realignment of duties on a functional basis or contracting for services may be feasible alternatives.

16/ Thirty-seven of 56 upstate county highway departments administer and maintain less than 400 miles of county highway. Fifteen counties contain between 400 and 600 miles of county highway. Only four highway departments have responsibility for more than 600 miles of county roads and only one has more than 800 miles of highway.

17/ The functional form of the regression equation prevents the long-run average cost curve from turning upward to indicate diseconomies of size. However, alternative formulations which would have demonstrated the existence of diseconomies of size were tried unsuccessfully.

The highway maintenance and snow removal functions are essentially independent operations. Snow and ice removal is provided from November through March in most parts of the state and requires a specialized set of machinery. Highway maintenance and repair work is generally performed during the period of April through October and requires a specialized set of machinery. The existence of substantial economies of size in providing either maintenance or snow removal separately might suggest realignment of service areas by function, rather than consolidation of units. For example, evidence of economies of size in providing snow removal may suggest that the county and town highway departments consider contractual arrangements that would reduce the highway cost to the citizens of both of those units government.18/ The remainder of the study is oriented toward analysis of economies of size in providing the maintenance, snow removal and administration functions separately. Conclusions and the implications for future research are also drawn.

Maintenance

The highway maintenance model hypothesized for this analysis is presented in (7).

$$(7)\quad Y_m = b_o + b_1\,CB + b_2\,FV + b_3\,MV + b_4\,P + b_5\,PD + b_6\,Q + b_7\,RM + b_8\,RM^2 + b_9\,T$$

Each of the above variables is defined in Table 1. The parameters of this model were estimated using multiple linear regression. Again, variations in the quality and topographic indices bore little relationship to variations in highway maintenance costs. A number of alternative formulations of the maintenance cost model were estimated. Only road mileage, the number of county bridges and motor vehicle density were found to be statistically significant in explaining variations in highway maintenance costs.

The parameters of the final maintenance cost model were estimated using multiple linear regression and the resulting equation is presented in (8).

$$(8)\quad Y_m = \underset{(2.43)}{-634{,}580} + \underset{(5.95)}{1{,}716.70}\,RM + \underset{(3.19)}{2{,}964.50}\,CB + \underset{(22.45)}{2{,}947.60}\,MV + \underset{(.96)}{6{,}881.40}\,P$$

18/ Informal and formal agreements between town and county highway departments are common in New York State. In some cases, towns plow county roads, and in other cases, the county plows town roads. Most of these agreements have developed gradually based on convenience rather than economic analysis. The existence of economies of size in providing snow removal may suggest that these arrangements be encouraged to reduce costs.

Numbers in parentheses under the equation are t-values. All regression coefficients, with the exception of precipitation, are statistically significant at the 99 percent level. The adjusted R^2=.93. The regression coefficients indicate that an additional mile of county road increases maintenance costs by about $1,717; an additional bridge increases county maintenance costs by $2,964; and, an additional motor vehicle per square mile is associated with a cost increase of $2,948. The precipitation coefficient, while not statistically significant, indicates that an additional inch of annual precipitation is associated with a $6,881 increase in maintenance costs.

Derivation of the average cost curve for maintenance is analogous to the previous derivation of average highway cost per mile. First, each regression coefficient, with the exception of road mileage, is multiplied by its mean value and added to the constant, as follows:

$$(9) \quad Y_m = -634{,}580 + 1{,}716.70\ RM + 2{,}964.50\ (101.41) + 2{,}947.60\ (159.15) + 6{,}881.40\ (37.01)$$

$$(10) \quad Y_m = 389{,}841 + 1{,}716.70\ RM$$

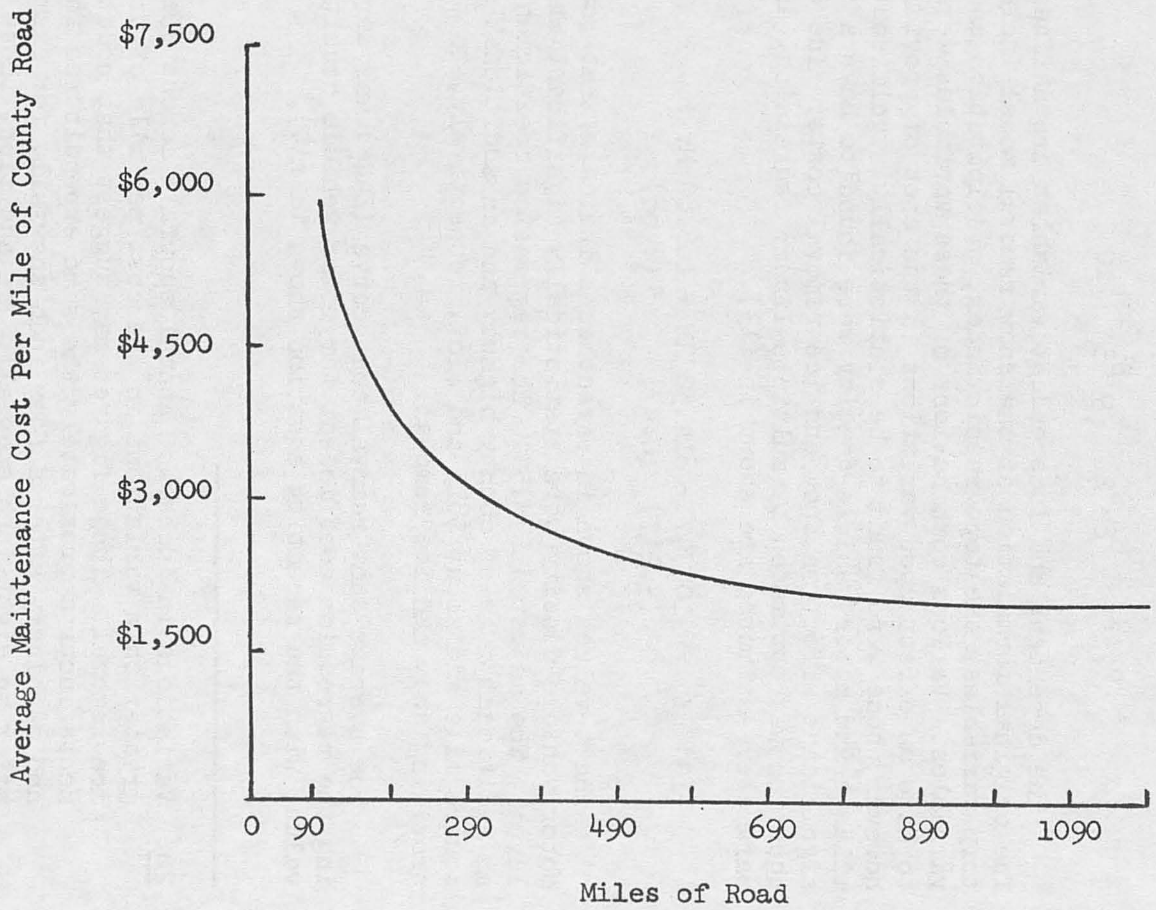
Then, (10) is divided by road mileage (RM) to get the long-run average maintenance cost (LAC_m) curve in (11).

$$(11) \quad LAC_m = Y_m/RM = 389{,}841/RM + 1{,}716.70$$

The average maintenance costs were calculated over a range of road mileage (Table 2) and the resulting long-run average cost curve is presented in Figure 2. The average cost of providing maintenance declines rapidly from $6,048 per mile at 90 miles of road to approximately $2,377 per mile at 590 miles of highway, indicating substantial economies of size. However, per mile costs decline slowly above 600 miles of highway reaching a minimum of $2,044 at 1,190 miles. These figures suggest that for highway departments maintaining relatively small amounts of highway, substantial per mile cost reductions may be achieved by expanding the number of miles of highway maintained. Consolidation of the maintenance function under a single centralized authority is probably not politically feasible. However, greater use of contractual and/or informal arrangements with one or more towns within a county may be feasible alternatives under the existing administrative structure.[19]

19/ An analysis of the per mile cost of highway maintenance provided by the towns and villages within each county would be desirable, but was not within the scope of this preliminary analysis. A more detailed analysis of town, county and village highway departments is currently being initiated.

Figure 2
Average Maintenance Cost Curve Per Mile of County Road



Snow Removal

The cost of providing "snow removal" includes expenditures for labor, materials and machinery used for snow and ice removal. The initial regression model formulated to explain variations in the cost of providing snow removal as a function of size of highway unit is shown in (12).

$$(12)\quad Y_s = b_o + b_1\,FV + b_2\,MV + b_3\,P + b_4\,PD + b_5\,RM + b_6\,RM^2$$
$$+ b_7\,S_1 + b_8\,S_2 + b_9\,S_3 + b_{10}\,T$$

The dependent and independent variables are defined in Table 1. The original formulation of the snow removal model included, as explanatory variables, the topographic index, precipitation and three snowfall variables. Various combinations of these variables were hypothesized to have an effect upon variations in the cost of providing snow removal, however, none were found to be statistically significant.[20] Only road mileage and motor vehicle density were found to have a statistically significant effect on snow and ice removal costs. The snow removal equation was estimated by multiple linear regression, and the resulting parameter estimates are shown in (13).

$$(13)\quad Y_s = \underset{(-.217)}{-10{,}747} + \underset{(6.47)}{814.52}\,RM + \underset{(2.68)}{166.80}\,MV$$

The t-values shown in parentheses indicate that road mileage and motor vehicle density were statistically significant at the 99 percent level. The adjusted R^2=.50. The regression coefficients indicate that an additional mile of county highway and an additional motor vehicle per square mile add about $815 and $167, respectively, to the total cost of providing snow and ice removal.

The average snow removal cost curve (LAC_s) was derived by multiplying the regression coefficient for motor vehicle density by its mean value, with the resulting equation shown in (14).

20/ Variations in inches of annual snowfall across the state are much greater than variations in the cost per mile of providing snow and ice removal. These figures may suggest that county highway departments incur approximately the same expenditures for labor, materials and machinery after a four inch snowfall, for example, as they do after an eight inch snowfall. In addition, these results may be related to the expectations of the people in the community. That is, people in those areas of the state where snowfall is light may expect the highway department to plow, salt and sand after a light snow, whereas people residing in counties receiving large amounts of snowfall may not expect action unless driving conditions are seriously impaired.

(14) $Y_s = 15,767.39 + 814.52 \text{ RM}$

Then, (14) is divided by road mileage to get the average cost curve.

(15) $LAC_s = Y_s/RM = 15,767.39/RM + 814.52$

Average snow and ice removal costs were calculated over highway mileages ranging from 90 to 1,190 miles (Table 2) and these costs were plotted against road mileage in Figure 3. Snow and ice removal costs per mile decline only slightly over the entire range of county highway mileages. Costs per mile range from a maximum of almost $990 per mile for highway units containing 90 miles of county road to about $828 per mile for county units containing 1,190 miles of county highway. Above about 490 miles of highway, the average cost curve is virtually horizontal.

These results indicate that cost reductions to be gained at the county level by expanding snow and ice removal mileages, either through consolidation or formal and/or informal operating arrangements, are likely to be small. It should be emphasized that this analysis is preliminary and applies only to county highway units. Research into the costs of providing various highway functions by town and village highway departments should be undertaken. The existence of substantial economies of size in town or village snow and ice removal operations may suggest that towns plow county and village roads rather than vice versa. Additional research regarding highway department costs is sorely needed.

Administration

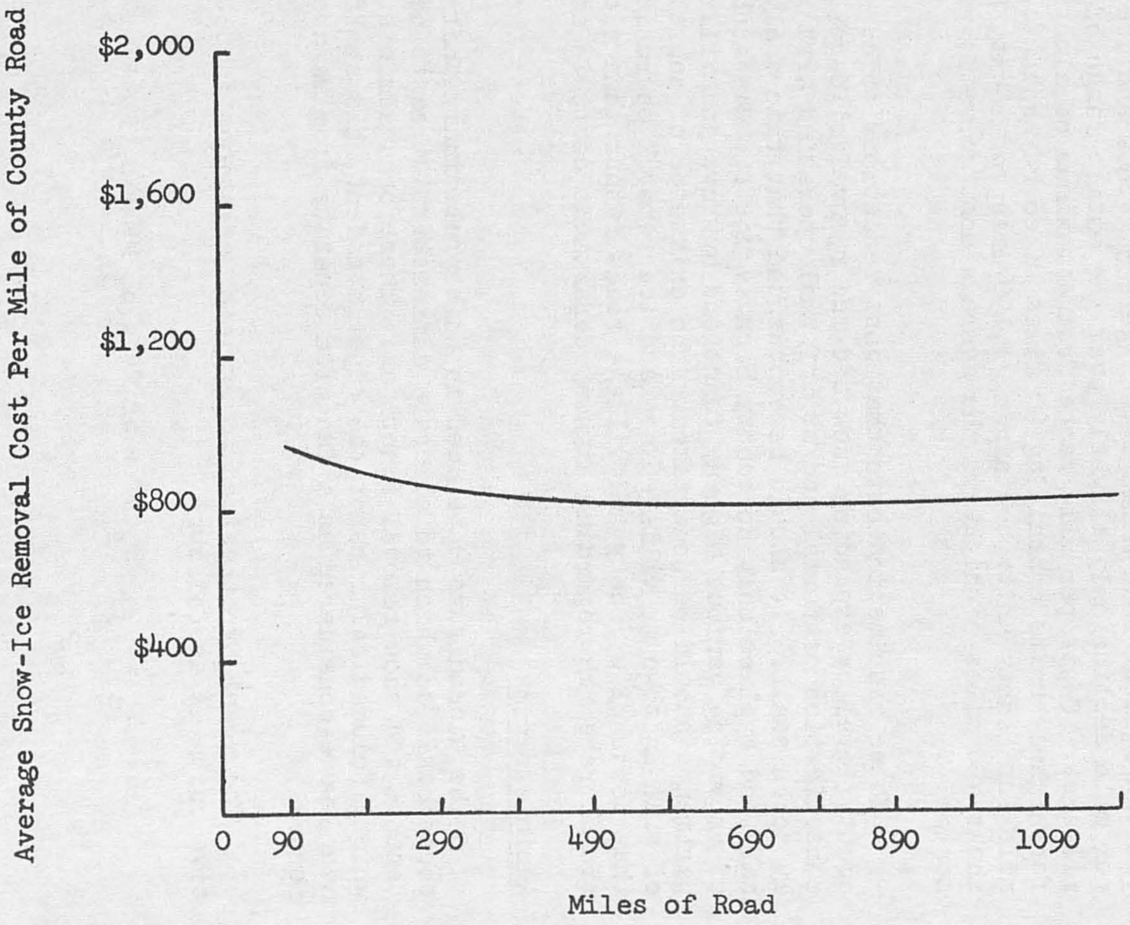
The expenditure data used in this preliminary analysis provided no sound basis on which to allocate administrative costs between the maintenance and snow removal functions. Therefore, administrative costs, which included salaries of the superintendent, his staff and the engineer, were considered as a function separate from maintenance and snow removal.

The model hypothesized to explain variations in total administrative costs is as follows:

(16) $Y_a = b_o + b_1 \text{ DV} + b_2 \text{ FV} + b_3 \text{ MV} + b_4 \text{ PD} + b_5 \text{ Q} + b_6 \text{ RM} + b_7 \text{ RM}^2$

The dependent and independent variables are explained in Table 1. A zero-one dummy variable (DV) was included in the administration model in an attempt to distinguish between counties whose administrative structure included a public works department and those maintaining the traditional highway department. Administrative expenditures were

Figure 3
Average Snow-Ice Removal Cost Curve Per Mile of County Road



expected to be considerably higher in counties with public works departments because these departments perform several functions, such as providing sewer and water services, not performed by traditional highway departments.

Several variations of the administrative cost equation were estimated. The quality index, for reasons previously explained, was of little value in explaining variations in total administrative costs. Full value of real property per capita, motor vehicle density, population density and the public works dummy variable were all highly correlated. The final regression equation included the public works dummy variable because it was thought to have a more substantial impact on administrative costs than full value of property, motor vehicle density or population density.

Parameter estimates of the final administrative cost equation are presented in (17).

$$(17)\quad Y_a = \underset{(4.08)}{157{,}630} - \underset{(-3.52)}{591.33\ RM} + \underset{(5.61)}{.87\ RM^2} + \underset{(5.15)}{135{,}090\ DV}$$

Numbers in parentheses are t-values. All coefficients are significant at the 99 percent level. The adjusted R^2=.67. Regression coefficients may be interpreted in the usual manner, except for the coefficient of the public works dummy variable. Use of the zero-one dummy variable makes it possible to distinguish between the administrative cost equation for counties with public works departments and those with highway departments. The dummy variable regression coefficient indicates a difference of $135,090 in the value of the intercept for the public works equation as opposed to the highway department equation.

The average cost curve for highway administration was obtained by multiplying the dummy variable regression coefficient by its mean value, adding the product to the intercept, and dividing through by road mileage.

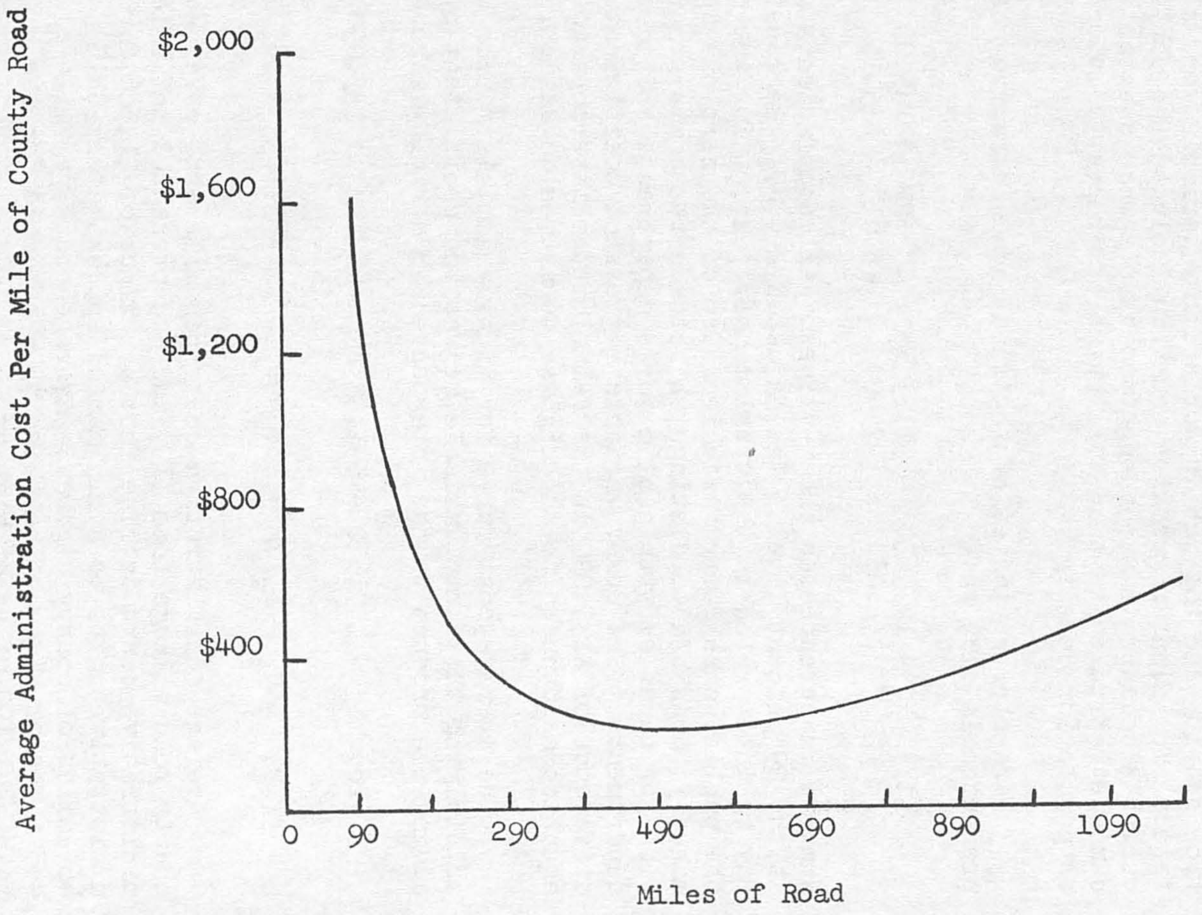
$$(18)\quad Y_a = 157{,}630 - 591.33\ RM + .87\ RM^2 + 135{,}090\ (.23)$$

$$(19)\quad LAC_a = Y_a/RM = 188{,}990.10/RM - 591.33 + .87\ RM$$

Average administrative costs per mile were obtained by substituting county road mileage into (19) and are presented in Table 2. Average administrative costs decline from a maximum of $1,586 for the smallest administrative units to a minimum of approximately $215 per mile at about 465 miles of county highway. Average costs per mile rise beyond about 465 miles of highway, reaching $598 per mile for the highway unit containing 1,190 miles of highway.

The shape of the average cost curve for administration is shown in Figure 4. The curve indicates that substantial economies of size in providing administration may occur up to 465 miles of county highway.

Figure 4
Average Administration Cost Curve Per Mile of County Road



At that point, diseconomies of size begin to occur. That is, the cost per mile of providing highway administration rises as the size of highway units rises beyond about 465 miles. These results have implications for both small and large highway units. Forty-three county highway departments administer less than 465 miles of county highway. Substantial economies of size may be achieved by expanding the number of miles administered by many of those units. However, 13 county highway departments administer between 465 and 1,190 miles of county roads. These results indicate that costs per mile for administration may be reduced by reducing the number of miles of highway administered by those units. In addition, these results may add credence to the growing feeling among some political scientists and public administrators that "bigger units are not always better," either in terms of efficiency or the quality of services provided.

Summary and Implications for Research

This paper reports the results of a preliminary analysis of the cost of providing county highway services in New York State. An analysis is performed of the total and average costs of providing county highway services using 1970 expenditure and budget data for 56 upstate counties. In addition, analyses are made of the cost of performing the separate highway functions of maintenance, snow and ice removal, and highway administration.

The results of this preliminary analysis indicate that there may be economies of size to be gained by expanding the number of miles of highway covered by highway units up to about 400 miles of road. Beyond about 400 miles, costs per mile appear to continue to decline, but at a much slower rate.

The average cost of providing highway maintenance varied from $6,048 per mile for the smallest highway units to $2,377 per mile at 590 miles of highway, indicating declining per unit costs as highway mileage increases. Beyond 590 miles, per unit costs declined slowly with increasing highway mileage.

The average cost of providing snow and ice removal declined only slightly over the entire range of county highway units. Costs per mile ranged from a maximum of about $990 per mile to a minimum of about $828 per mile. The average cost curve was virtually horizontal for highway mileages above about 490 miles.

The average cost curve for highway administration exhibited both economies and diseconomies of size. Administrative costs per mile declined from $1,586 per mile for the smallest administrative unit to $215 per mile at about 465 miles of county highway. Beyond about 465 miles, costs per mile increased, reaching $598 per mile for the highway unit containing 1,190 miles of highway.

These preliminary results indicate a combination of economies and diseconomies of size, with interesting implications for the provision of the maintenance, snow removal and administration functions. County highway departments may be able to reduce the costs of providing highway services in several ways. Consolidation of county highway units does not appear to be politically feasible. However, cost reductions may be achieved through expanding the number of highway miles administered and maintained by smaller highway units. Formal contractual arrangements or informal operating agreements appear to be politically and economically feasible. However, additional analysis is needed to provide the basis for establishing cost-reducing arrangements or agreements for counties.

In addition, further analysis is needed of the cost of highway services provided by town and village highway departments. Because towns and villages are so numerous and their budget and expenditure data are not generally available from secondary sources, it would be costly and time consuming to perform a complete analysis for all town and village units. A more realistic approach may be to analyze the relationships among county, town and village highway departments within a sample of rural counties. Such an analysis should take account of existing informal and formal arrangements among county, town and village highway departments. Realistic recommendations can only be made in the light of a more detailed analysis of the cost of providing county, town and village highway services. This preliminary analysis has been particularly useful, however, in suggesting the potential for future research into the costs of providing highway services.

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