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(continued on back cover)

Royal Commission on Local Government in England

RESEARCH STUDIES
3

Economies of Scale in Local Government Services

by

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FOREWORD

This study of economies of scale in local government services by the Institute of Social and Economic Research, University of York, is the third in a series of research studies being published for the Royal Commission.

The views expressed are solely the responsibility of the authors, not of the Royal Commission.

Royal Commission on Local Government in England

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CONTENTS

I. INTRODUCTION

The services we have studied are functions associated with Local Authority Housing, Highways and Health Services. The ways in which economies of scale can arise in these services are numerous, partly because the services themselves include a number of functions ; limitations of time and data have, however, restricted the study to a few types of economy of scale and sometimes to what may loosely be termed " scale effects ". The particular approach adopted in each service will be explained in the relevant section. In this section we will explain the nature of the problem as we see it, and what assumptions and restrictions we consider necessary if answers are to be obtained: this section will be followed by a brief exposition of the statistical technique employed, and its relation to the problem. The specific problems of each service will be discussed in separate sections, followed by a discussion of the statistical results. Finally, a summary chart (with explanatory notes) of scale effects is provided, followed by an Appendix of sources, tables and graphs.

Education is financially the most important single service provided by a Local Authority, but this service is being studied by a different group. After Education, however, we have looked for services of financial importance, that are also susceptible of statistical analysis.

ECONOMIES OF SCALE

The economic theory of the firm provides the most straight forward example of scale effects. In the case of a single firm, producing x units of a single, homogeneous good, its total costs of production depend upon the level of output. In the short run the firm has fixed costs attributable to its scale of plant, but in the long run all costs are variable as the scale of plant can be adjusted to that producing x at minimum cost per unit. Since the scale of plant determines the techniques possible, the possibility of combining " lumpy " factors, and also the need for co-ordination and control, the relationship between total cost and output will not be simple.

(1) $y=ax-bx^2+cx^3$ is usually accepted as a description of the long run total cost function, with no element of fixed costs. This yields :—

(2) $\frac{y}{x}=a-bx+cx^2$, the familiar U-shaped average cost function, whose minimum point is the long run " optimum " rate of output. As we discuss below, the statistical analysis performed, using cross-section data, is designed to obtain estimates of this long run average cost curve.

There may be special reasons for a firm having higher or lower costs than its scale of output would indicate: local supplies of raw material or labour, and local weather conditions are examples. In this case (2) must be modified to:—

(3) $\frac{y}{x}=a-bx+cx^2+d_1z_1+\ .\ .\ .\ d_nz_n$, where the z variables indicate the environment within which the firm operates.

It is necessary to introduce the z variables, since, if they are correlated with x but omitted, biased estimates of a and b would be obtained*. Unfortunately, by including them, their correlation with x raises the problem

* See E. Malinvaud: *Statistical Methods of Econometrics*, (North-Holland, 1966) pp. 263–266, for an exposition of the theory of omitted variables.

of multicollinearity: when this happens the estimates of a and b, in which we are interested, are not systematically biased, but their range of probable values can become uncomfortably wide. The statistician must try to steer a course within this basic dilemma of most economic situations.

When we consider the problem of economies of scale in local government activities, both "scale" and "cost per unit of output" must be defined within this context.

Considering "cost per unit of output" first, the heterogeneity of output is the principal problem. This most obviously presents itself when a Service performs several distinct functions (the Highways Service is responsible for construction of new roads and bridges, and for improvement and maintenance of existing roads and bridges): in this case reasonably homogeneous functions must as far as possible be distinguished for separate study. Availability of data will constrain the distinctions feasible.

Within apparently homogeneous functions, differences in quality and quantity may exist. For some services, the best available data is expenditure per head, with no unit of output available; again, the unit of output may itself be far from homogeneous. Examples of the latter are "visits" of home nurses, which may vary considerably in duration and content depending on the circumstances; and square footage of council houses, which may conceal considerable differences in finish and equipment. Even if we had data on costs per homogeneous unit of output, the costs may be affected by the environment within which the service operates: this is analogous to the z variables in (3) above. Many of these difficulties exist for firm data, but can be to some extent resolved by the market mechanism, which evaluates output according to consumers' criteria: thus quality differences will be reflected in different market prices, a piece of information obviously not available for publicly-owned services.

Finally, the local authorities are not fully autonomous units, straightforwardly comparable with each other. They are interdependent for many services, have different administrative structures reflecting their different degrees of autonomy, and are dependent on central government for finance, for much overall policy, and for many ancillary and complementary services.

To some extent the distortions due to these non-homogenieties and similar difficulties will be associated with scale: it is safer to assume that this is so. Accordingly, if they can also be associated with other variables, the theory of omitted variables tells us that these other variables should be included to obtain unbiased estimates of scale effects. We will therefore include a number of explanatory variables other than scale, some of a general socio-economic nature and some more specific to the service considered, in the hope that the scale effect can be "purged".

In the theory of the firm, "scale" usually refers to total output, as indicated above, although some account is often taken of the degree of capacity utilization involved*, but capacity is even less easy to define in this context than in the theory of the firm. For example, in two of the functions analysed below, the construction of houses and the maintenance

* See M. Friedman, "Comment" on C. A. Smith, "Survey of the Empirical Evidence on Economies of Scale" in G. Stigler (ed.) *Business Concentration and Price Policy*, (Princeton, 1955).

and minor improvement of highways, the authority generally depends to a greater or lesser extent on outside contractors, " capacity " thus tending to infinity.

The procedure adopted by us is to use output as a measure of scale, in spite of its limitations, but to concentrate our attention on population as a scale variable. Population provides a measure common to all services, thus allowing comparisons to be drawn between different services for any authority. This variable will be correlated with output, and will also be representative of the size of the organisation involved in the provision of all local government services.

Finally, in the case of Local Authority Health Services, we analyse the ratio of administrative to total expenditure on this service. The arguments for using this variable are given in the relevant section below: the analysis depends upon the idea that the lower the ratio, the higher is efficiency, given certain important assumptions.

II. STATISTICAL TECHNIQUE

The statistical technique adopted to discover the significance and quantitative importance of each variable was multiple regression analysis. In this technique variations in the chosen dependent variable are partially " explained " by variations in the chosen independent variables, and the amount of explanation afforded by each variable is the measure of its " significance " ; at the same time, forgetting for a moment the significance of the variable, its quantitative importance is measured by the amount of variation in the dependent variable to be expected for a given variation in the particular independent variable.

The first characteristic, the significance attached to the variable, is indicated in our tables by the t-value: in general, if the value of t is greater than +2 or less than −2, we can be at least 95 per cent confident that this particular independent variable has a positive or negative effect, and there is less than a 5 per cent probability that this is just a chance result thrown up by our particular sample when the variable really has no effect on the dependent variable. If the value of t lies between 1 and 2 we can be between 64 per cent and 95 per cent confident that some effect exists. The proportion explained by each equation, or collection of independent variables, is given by R^2—in the tables we give R or R^2 for each equation and $\triangle R^2$ for each variable (another way of measuring significance): the remaining explanation can be attributed to the very large number of other independent variables which have not been included for one reason or another (non-quantifiability, unavailability, or relative unimportance).

The quantitative importance of the variable is indicated by its regression coefficient, the β value. Thus if the β value of a particular independent variable were, say, 5, we would expect (to the relevant degree of confidence) that an increase or decrease of 1 unit of that independent variable would lead to an increase or decrease of 5 units of the dependent variable. Thus the t-value and the regression coefficient are related, insofar as the t-value indicates the width of the range around our estimated β within which we can expect the true value of β to lie, and particularly, whether this range includes zero. If we are prepared to adopt *a priori* the hypothesis that the true value of β is not positive or not negative, we can use a " one-tailed test ", which is more likely to reject the hypothesis that the true value of β is zero. This test is suggested at some points in the discussion below.

The two paragraphs above depend upon two assumptions :

(1) that our sample of local authorities was randomly chosen, or is " representative " ;

(2) that the unexplained variations in the dependent variables (the residuals) are normally distributed.

The representativeness of the sample in time depends upon 1964–65 being a normal year. The authorities included were all those for which the data used were available. The normality of the residuals has not been tested, but on *a priori* grounds, we would expect residuals comprising the sum of a larger number of independent effects to be normally distributed.

FORMS OF FUNCTIONS ESTIMATED

The regression functions fitted are of the form

$$Y=\alpha+\beta_1X_1+\gamma_1X_1^2+\beta_2X_2 \ldots +\beta_nX_n.$$

Thus the function is polynomial in X_1 : in the actual equations estimated, X_1 is usually the population of the authority, the other variables all being fitted linearly. If β_1 is negative, and γ_1 positive, the function is U-shaped with respect to X_1. At the minimum point of the U-shaped curve, the " optimum " population for the particular activity and type of authority might be said to lie*. It is, of course, quite possible that the minimum of the function lies beyond the range of observations, which makes it purely speculative, or that the function is other than U-shaped (as will appear below). Since our data is a cross-section of authorities over a short period of time, we are analysing the *differences* between authorities. If all authorities have, over the long run, more or less adjusted their overheads to suit their requirements, the cost function can be regarded as long run†, and it is permissible to draw certain intertemporal conclusions about likely patterns of adjustment if, say, scale variables changed.

The estimation of a total cost function rather than an average cost function would have been possible, but in general the variance of total costs around their mean value is greater for greater levels of output, or scale : this reduces the " efficiency " of the estimates of the β's. By dividing through by output, we can expect that this problem will be largely overcome‡.

THE RESULTS

The statistical analysis was performed by electronic computer, and in the case of some services it was possible to obtain " best " equations: the latter indicated the combination of a given number of variables providing maximum explanatory power. The Appendix contains summary tables of the results, together with a description of the variables used and their sources. In the following sections we discuss the results for each service individually, and offer

* For a similar application, see John Riew, " Economies of Scale in High School Operation ", *Review of Economics and Statistics*, August, 1966.

† This depends upon the assumption that the absolute rather than the relative magnitudes of the X's are the determining factors.

‡ This is the problem of " heteroscedasticity ", explained in e.g. E. Malinvaud, *op. cit.*

what appear to us to be plausible explanations for some of the results: it should be emphasised that other explanations may be more satisfactory, our principal objective being to demonstrate whether or not relationships exist.

III. HOUSING

Procedure and Assumptions

Our dependent variables in Housing are cost per foot super and Supervision and Management costs per dwelling. The former is the total cost of the superstructure of the house (excluding cost of land, architects' fees, drainage and sewerage, foundations, etc.) divided by the internal floor area; figures are available for one, two and three-bedroomed "traditional" houses, but we chose to analyse the three-bedroomed houses, since those figures are most complete. Given that the building process varies little for these conventional houses, our choice of a three-bedroom unit need not be equally "representative" of local authority building, so long as it is comparable between authorities. In other words, scale effects from large authorities, or ones with large building programmes, will, we assume, apply to the whole of conventional house building programmes in much the same way.

Supervision and management expenditure per dwelling relates to the whole stock of local authority dwellings, whether in blocks of flats, or acquired from private owners: the heterogeneity of the denominator must be important in any analysis. A breakdown of "Supervision and Management" also reveals that these expenses include items incurred essentially in the construction of new houses, rather than in the maintenance of the existing stock: the importance and cost of the Architect's and Engineer's Departments depend on the extent to which the authority is still building. In this context, a further factor to be considered is the practice of many smaller authorities (mainly R.D.C's. and U.D.C's.) to contract out the architects' and engineers' functions along with the actual construction, so that the cost appears in the capital account, rather than in Supervision and Management.

The heterogeneity of the housing stock will to some extent be related to the second Moser and Scott variable, labelled "population change, 1931–51" which indicates the vintage of much of the housing stock: this variable is unfortunately unavailable for most N.C.B's. and all R.D.C's. and U.D.C's., and therefore two analyses of N.C.B's. were performed.

Of the two sources of heterogeneity in Supervision and Management, in the numerator, the rate of building is indicated by the number of houses completed. The contracting-out by smaller authorities is not readily picked up, and some positive bias in the scale effect measured must be suspected; this effect may be eliminated in part by the separate analyses of the different types of authority.

When analysing cost per foot super, alternative scale variables include the total stock of dwellings, the product of a penny rate, and the number of houses completed during the year; in the case of Supervision and Management, the total stock of dwellings is used.

Variables included because of their possible influence on quality and on the degree of "cost-consciousness" in an authority include "Social Class" (see definition in Appendix), Population Density, Rateable Value per capita, and

Rate Subsidy as per cent of total income on the housing account. As a rough measure of relative labour costs, regional average weekly earnings were used.

The effects of these variables on the dependent variables is discussed in detail below.

In an attempt more precisely to determine the effect of building conditions on cost per foot super, a separate analysis was carried out introducing the average site density of building sites in each authority, together with the average size of site as a new scale variable. At the same time the per cent of direct labour employed was used as an independent variable, as this has often been suggested as a possible determinant of costs.

FINDINGS AND EXPLANATIONS

Effects of "Scale" on Efficiency

(*a*) *Population*

The first important scale variable considered is population. Both with regard to "cost per foot super" and "supervision and management costs per dwelling", which in this study are considered as rough measures of "efficiency", our statistical observations refute the hypotheses concerning a U-shaped cost curve and the "optimum" population size of a local authority for all the different categories of local authorities (except for the Urban District Councils for "supervision and management costs", discussed below).

Considering "cost per foot super" as the relevant dependent variable, our findings for the County Boroughs suggest the opposite of what has been the common view about the effect of an increase in the population or "size" of a local authority on its efficiency. The findings for the County Boroughs refute not only the prevalent view that economies of scale would be achieved by increasing the present "size" of such local authorities, but also provide some evidence that diseconomies of scale operate with an increase in the population size*. Of course, our evidence cannot be considered conclusive, and is not quite significant if the conventional five per cent level of significance is chosen. Again, with regard to the non-County Boroughs and the Rural District Councils, our findings strongly refute the notions of a U-shaped cost curve and the "optimum" population size, but rather suggest an inverted U-shaped cost curve for such authorities. Diseconomies of scale operate with an increase in the population size until about 60,000 population size is reached, when "cost per foot super" is at its maximum. An expansion of the population size beyond 60,000 might lead to diminishing costs. It seems, however, worth emphasising here that as the cost curves are of the inverted U-shaped form, the non-existence of the point of minimum cost invalidates the notion of an observable "optimum" population size of a local authority, "optimum" being defined as that which gives the minimum cost. Besides, so far as the Rural District Councils are concerned, only 12 out of 100 such Councils taken as our sample have a population size more than 60,000: therefore, the evidence of diminishing

* These conclusions are based on the results summarised in Appendix table on Housing: they are, however, consistent with the analysis under *Types of Authority*, introducing some new variables.

cost beyond 60,000 population size is rather weak, and the curve could as well be asymptotic beyond that population size. With regard to the non-County Boroughs, however, 20 out of 89 included in our sample have a population more than 60,000, and diminshing " cost per foot super " beyond 60,000 population size for them therefore seems plausible. But as the cost curve is of the inverted U-shape, a reduction of " cost per foot super " could be achieved not only by increasing the size beyond 60,000 but also by reducing the size below 60,000, the latter requiring a change of size for only about 22 per cent of the total non-County Boroughs.

Our findings with regard to the " supervision and management costs " for the non-County Boroughs and the Rural District Councils again provide some evidence that such costs vary directly with population size: the hypotheses concerning economies of scale, scale being interpreted as population size, are again strongly refuted. In the case of the Urban District Councils, however, our findings suggest a U-shaped supervision and management cost curve with relation to population, such costs being at their minimum when the population size of an Urban District Council is about 40,000 beyond which tending to rise. Therefore an increase in their size beyond 40,000 would also give rise to diseconomies of scale.

Our above discussion and findings are concerned with economies or diseconomies of " scale " *within* each different-category of local authority. These authorities are different not only with regard to " scale " but also with regard to the other explanatory variables (e.g. social class, population density, etc.) in the analysis, and with regard to their administrative structure (the single or multiple tier system). The graphs in the Appendix show that, keeping population constant, " cost per foot super " and " supervision and management costs " vary greatly *between* the different categories of local authorities. For the actual ranges of observations, the local authorities can be ranked in ascending order for both types of costs as follows:

(1) Urban District Councils,

(2) Rural District Councils,

(3) Non-County Boroughs,

(4) County Boroughs.

By looking at the quantitative differences in such costs between different categories of local authorities, it seems that the other explanatory variables and the administrative structure* (the tier system) together are relatively much more important than the " scale ", in their influence on our measure of " efficiency ".

The finding that per capita (rate and grant-borne) expenditure on housing by a local authority tends to diminish with increasing population size is not incompatible with the findings described above. Expenditure on housing (per capita) tends to diminish with increasing population size of a local authority because either (1) the " need " or demand for such housing is not likely to increase proportionately with an increase in population, and/or (2) the larger the local authority, the greater are the organisational and administrative difficulties in reaching revenue and expenditure decisions and expediting

* See section on *Types of Authority*, however, for discussion of an attempt to isolate the effects of administrative structure by dummy variables.

them so that the *gap* between expenditure and " need " may become wider. If the second explanation is true, then diminishing per capita expenditure with an increase in the population size of a local authority could be regarded as signalling further " inefficiency "* with increasing size of local authorities: one may consider widening of the gap between expenditure and need as another notion of " inefficiency ".

The other scale variables considered are: (i) the 1d. rate product, a measure of total Rateable Value or wealth of a local authority; (ii) the number of dwellings completed in one particular year by a local authority; (iii) the stock of dwellings in a local authority.

(*b*) 1*d. Rate Product*

It may be argued on *a priori* grounds that an increase in total rateable value or wealth would have a negative effect on our measures of " efficiency ". Firstly, because a larger rateable value provides a larger tax base and, therefore, assuming rate poundage (or tax raising " effort ") remaining constant, a larger revenue from rates, which may encourage a local authority to be " extravagant " in its spending (i.e. less efficient) and/or to build better houses. The results suggest such an effect of " 1d. rate " on " cost per foot super " in the case of County Boroughs and Rural District Councils. For these authorities " cost per foot super " tends to increase with an increase in " 1d. rate ". This positive effect on " cost per foot super " is significant at the 6 per cent level of significance (with a one tail test).

(*c*) *Number of Houses Completed*

It may also be argued on *a priori* grounds that the greater the number of houses built by a local authority, the smaller would be the cost per house built (or the smaller would be the cost per foot super), all other variables remaining constant, because of economies of scale. Such a hypothesis, however, is not verified except in the case of a sub-group of non-County Borough (N = 23): in their case, the corresponding null hypothesis could be rejected at about the 9 per cent level of significance (with a one tail test). Our findings thus suggest some economies of scale with respect to this variable for a particular group of local authorities, but the evidence is rather weak.

(*d*) *Stock of Dwellings*

Again, it may be argued that the supervision and management cost per dwelling would fall with an increase in the stock of dwellings, through economies of scale. Our findings suggest such economies of scale for non-County Boroughs and Urban District Councils.

Supervision and management cost per dwelling and the stock of dwellings, however, seem to vary directly for Rural District Councils. In their case, the supervision and management function is often carried out by the Public Health Department. The smaller the R.D.C., the greater usually is the

* Larger authorities sometimes encounter more physical obstacles to new house building in slum clearance and site preparation: this may also increase the " gap ".

tendency for this function to be so delegated. As the statistics of supervision and management costs do not take account of this effect, the statistical analysis shows supervision and management costs per dwelling varying directly with the stock of dwellings. This finding may be disregarded because of the serious underestimation of this cost for the smaller Rural District Councils.

Our results also show that cost per foot super is not significantly affected by the stock of dwellings, except in the case of Urban District Councils. In their case, the reduction in cost per foot super with an increase in stock of dwellings is significant at the 8 per cent level of significance (with a one tail test). This is plausible because a larger stock of dwellings implies greater experience in house building, which may help to reduce "cost per foot super" in some cases.

In addition to the above-mentioned scale variables, other explanatory variables are incorporated in the multi-variate analysis for the reasons stated above. The effects on our three different dependent variables for housing are summarised in the Tables given in the Appendix: such effects are discussed below.

Social Class

Our empirical findings suggest that cost per foot super and supervision and management costs per dwelling vary directly with social class (at the 5 per cent level of significance), whereas per capita rate and grant-borne expenditure on housing varies inversely with social class (at the 5 per cent level of significance, except for the Rural District Councils for which the statement holds good at about the 10 per cent level of significance) for all the different categories of local authorities.

Although conceptually, for comparable purposes, the measure "cost per foot super" should be computed on the basis of the costs of "standardised" houses with no quality differences, it was not possible for us to devise such a measure. The "traditional" houses built by different local authorities vary in quality: any adjustment made for quality differences is bound to be arbitrary, and, therefore, no such adjustment is made in this study. If "quality" could be defined in terms of some measurable unit, then our measure "cost per foot super" would be equal to (cost per unit "quality") x (total units of "quality" per foot super).

A plausible explanation of the direct variation in the "cost per foot super" with social class may lie in the probable direct variation in the "total units of quality per foot super" with "social class" rather than in the variation of the "cost per unit quality". It is highly likely that a local authority with a "social class" index more than average would build council houses of more than average "quality", and vice versa. The same explanation could be offered for the direct variation of the "supervision and management" costs per dwelling with social class. A local authority with a social class index more than average possibly tends to employ better qualified and better paid personnel for supervision and management, the "quality" of which is likely to vary directly with "social class". Alternatively, more personnel of a given calibre could be employed to increase the quantity of supervision and management provided in a "higher" social class area*.

The rate and grant borne expenditure on housing per head by the local authorities tends to vary inversely with social class. Such a finding is sensible, because with an increase in the "social class" index there is less demand or "need" for subsidies for building new council houses. The "upper social class", which includes professional and higher income groups, tends to prefer and be able to afford to buy their own houses.

Average Weekly Earnings

The "cost per foot super" and "supervision and management costs per dwelling" may be different for different local authorities, because of differences in wages and salaries paid to local government employees, and also because of differences in costs of materials used for house building. It was not possible for us to obtain an inter-regional index of costs of materials used for house building; and our measure of average weekly earnings is also a very crude index roughly approximating to the differences in wages and salaries paid by different local authorities. Nevertheless, our empirical findings (see Appendix table), based on this index, suggest that supervision and management costs per dwelling vary directly with "average weekly earnings". Supervision and management service is highly labour intensive, and, therefore, if a local authority needs to pay higher wages and salaries to its employees, costs for such services obviously tend to rise.

The relationship between "average weekly earnings" and "cost per foot super", however, is not so clear cut. Our findings show that they vary directly for County Boroughs and Urban District Councils, but vary inversely for Rural District Councils. The explanation for such apparently contradictory findings may lie in the different elasticity of substitution of capital for labour for different categories of local authorities. It is likely that the elasticities of substitution of capital for labour is lower for the bigger local authorities (County Boroughs and Urban District Councils), because the number of houses built within the boundary of such authorities is fairly large and the use of heavy capital equipment or mechanisation is already achieved to a much greater extent. But for the smaller local authorities (such as Rural District Councils), within whose boundary a smaller number of houses are built, it is likely to be less economic to use heavy capital equipment or mechanised methods for building houses. As labour becomes more and more expensive, it provides a greater incentive and scope to substitute capital for labour. The process of such substitution or mechanisation tends to reduce costs.

Our findings also suggest that rate and grant borne expenditure on housing per capita tends to diminish with an increase in "average weekly earnings" (except for the Rural District Councils, whose per capita housing expenditure is hardly affected by variations in the "average weekly earn-

* This conclusion about the effect of social class on Supervision and Management costs is obviously somewhat controversial, contradicting widely accepted notions: more research on this point could prove valuable.

ings "). It is shown above that "cost per foot super" and "management and supervision costs" vary directly with "average weekly earnings" (except for the Rural District Councils). As the variation in the latter is positively related with the variation in the cost per unit of housing service, it is likely that the expenditure on housing per capita would tend to fall with an increase in "average weekly earnings". This is reasonable under the assumptions that the cost per unit of other public and/or private goods and services, which are less labour intensive, fall relative to that of the housing service, and that there is considerable elasticity of substitution by the public sector between goods and services whose relative costs change; the latter assumption is consistent with the idea of vote-maximising government*. Our findings for the behaviour of per capita housing expenditure for the Rural District Councils provides further support to such a view. As the cost per unit of housing service (including both the costs of supervision and management and cost per foot super) for the Rural District Councils is hardly affected by the variations in the "average weekly earnings", so also their per capita expenditure on housing is hardly affected.

Rateable Value per head and Rate Subsidy

Rateable value per head for a local authority provides a measure of per capita local tax base and also indicates roughly the degree of "wealthiness" of a local unit. On *a priori* grounds, one would think that the "quantity" and the "quality" of a local public service and the degree of "extravagance" would vary directly with the rateable value per head. Our findings suggest a positive relationship between "supervision and management costs" and rateable value per head for the Urban and Rural District Councils, which could arise for the reasons suggested above. Expenditure per head on housing is also found to vary directly with rateable value per head for the County and non-County Boroughs, possibly because with a higher per capita tax base, an authority is able to spend more (per head) on such services.

Similar *a priori* grounds may be put forth for the "effects" of increasing "rate subsidy". The higher the percentage of its expenditure which a local authority is able to finance from rates, the greater, one would think, would be the quantity of a service provided and the degree of "extravagance" (and also possibly the better would be the "quality" of the service provided). Our findings suggest that expenditure per head varies significantly with "rate subsidy" for *all* the different categories of local authority (see Appendix table). "Supervision and management costs" were found to vary significantly with "Rate subsidy" for the Urban District Councils. No significant relationship between "supervision and management costs" and "rate subsidy" was found for other categories of local authority. "Cost per foot super" was found to vary significantly with "rate subsidy" for the County Boroughs, but our findings also suggest an inverse relationship between those two variables for the Urban District Councils. The explanation for such different findings possibly lies in the different administrative and financial structure of the different categories of local authority.

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* See Anthony Downs, *An Economic Theory of Democracy*, (Harper & Bros., New York, 1957), for an excellent exposition of the vote maximisation hypothesis.

Type of Authority

Although obviously different regression equations were obtained using the same variables for different types of authority, it was thought worth investigating whether these differences could be expressed by "dummy variables". A simple scheme was adopted *, whereby the same β coefficients were fitted for all authorities, each authority being distinguished by a different constant term: the significance of the increment to the overall constant indicates the significance of the increment to, say, cost/ft. super due to the authority being, say, a County Borough.

It would be possible to consider a more complex scheme to allow for different β coefficients also, but when one is dealing with many independent variables, the system becomes too unwieldy.

The introduction of the three dummy variables added little explanatory power, and the constraint on the β's lost more explanatory power, leaving lower values of R. By increasing the number of observations to around 300, however, t-values were increased slightly.

In one case, the dummy variables were moderately successful. When analysing Supervision and Management, and including the additional independent variables discussed in the next section, we obtain the following equation for all authorities:

	Constant	*Population*	*(Population)²*	*Population Density*	*Average Earnings*	*Rate Subsidy*
β .	0·620	+0·00000328	−0·00000332	−0·0876	+0·00892	+0·0204
t .		1·43	−1·42	−0·41	2·54	1·40

	RV per capita	*Social Class*	*Dummy Variable I*	*DV II*	*DV III*	*Site Density*
β . .	+0·0238	+0·0726	+0·785	+0·428	+0·574	−0·0252
t . .	3·84	1·99	1·75	0·93	1·53	−2·41

	Average Number dwellings	*Per cent Direct Labour*
β . .	+0·000291	−0·00833
t . .	0·39	−2·78

(Inverted U-shaped function with turning-point for population at 500,000).

R=0·531

The contributions of each type of authority are therefore:

County Boroughs	+0·392
Non-County Boroughs	−0·178
Urban Districts	+0·073
Rural Districts	−0·287

Considering the higher t-values of D.V. I and D.V. III (County Boroughs *versus* non-County Boroughs, and Urban *versus* Rural Districts), and the net contributions, it is clear that Supervision and Management costs are highest in County Boroughs, and lowest in Rural Districts, *other things being equal.*

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* For an exposition of an identical scheme, see *Committee of Inquiry into the Impact of Rates on Households*, pp. 178–182. See also list of variables in Appendix.

When the last three variables in the equation above were omitted, the dummy variables became insignificant, but we regard the fuller equation as more reliable, being better specified.

Population Density, Site Density, and Use of Direct Labour

In the initial analysis of housing (see table in the Appendix), population density appeared to have a positive effect on both cost per foot super and supervision and management costs per dwelling, except in the case of the Rural Districts. In the light of discussion we attempted to refine our analysis, by including as additional variables (i) the average site density on "traditional" council building sites, and (ii) the average number of dwellings per site, as a new "scale" variable.

At the same time, the percentage direct labour employed in building by each council was introduced, as the effect of direct labour on costs has been much discussed.

Using the facility for choosing the "best five" variables, we obtained the following equations for *cost per foot super*:

(1) County Boroughs:

	Constant	*Population*	*Population Density*	*Rate Subsidy*	*Site Density*	*Per cent Direct Labour*
β ·	44·96	+0·00001091	−0·2595	+0·3894	+0·1544	−0·0254
t ·		2·39	−1·57	3·79	1·59	−2·54
			R=0·5568			

(2) Non-County Boroughs:

	Constant	*Population*	*(Population)²*	*Rateable Value per capita*	*Average Number Dwellings*	*Per cent Direct Labour*
β · ·	38·22	0·000265	−0·00182	+0·0836	−0·0260	−0·0677
t · ·		1·71	−1·26	1·31	−2·21	−2·38
			R=0·4390			

(3) Urban Districts:

	Constant	*Population Density*	*Rate Subsidy*	*RV per capita*	*Social Class*	*Site Density*
β · ·	35·57	+0·3142	−0·2320	+0·0499	+0·2628	+0·2215
t · ·		1·62	−1·69	0·81	2·40	1·95
			R=0·5095			

(4) Rural Districts:

	Constant	*Population*	*(Population)²*	*Average Earnings*	*RV per capita*	*Social Class*
β · ·	53·08	+0·000155	−0·00157	−0·0437	−0·0697	+0·211
t · ·		1·26	−1·18	−0·90	−1·29	2·63
			R=0·3288			

(5) All Authorities:

	Constant	*Population*	*Population Density*	*Social Class*	*Site Density*	*Per cent Direct Labour*
β ·	39·30	+0·00000662	+0·163	+0·218	+0·151	−0·0322
t ·		1·55	2·03	3·77	2·84	−2·07
			R=0·3757			

It is striking to note that population density and site density always occur *together* in these equations, or are both omitted as relatively insignificant. Thus it would appear that they exert separate influences on cost per foot super—this is borne out by the low correlations between the density variables. Clearly site density always has the correct sign, tending to raise costs. Population density is slightly less significant, and has a negative sign for County Boroughs. Both variables are omitted for non-County Boroughs and Rural Districts, not surprisingly in the latter where pressures of space are less of a constraint.

If high land values and high site densities go together, more compact houses will tend to be built: given the same fittings and finish, and a less than proportionately smaller number of bricks, etc., the reduced floor areas will produce higher costs per foot super. Population density has an overall positive effect, as shown in the fifth equation above, so that we can disregard the negative effect in the first equation: an explanation not involving site density must be sought for this result. Tentatively, one may suggest that population density (except in Rural Districts, where no effect was observed) may be regarded as a measure of urbanisation: urban costs, particularly labour costs, may be higher for those with a higher degree of urbanisation, thus positively affecting cost per foot super.

Except in the case of Urban Districts, Population and sometimes Population squared, occur as scale variables, the inverted U being less significant than the positive linear effects, indicating diseconomies of scale. (This is consistent with the initial results discussed above.) The average number of dwellings per site occurs in equation (2), however, indicating a form of economies of scale: only for non-County Boroughs was this effect observed.

The effect of direct labour is quite clear. In the County Boroughs and non County Boroughs, with means of 21·4 per cent and 10·7 per cent, this variable was significant at 5 per cent: in the Urban and Rural Districts, with means of 6 per cent and 4·3 per cent the variable was insignificant. The effect on costs is negative, where the use of direct labour is relatively great. It is, of course, possible that this effect is due to inconsistencies between private contractors' and local authorities' cost accounting, if the latter do not fully impute overheads to the cost of direct labour, as is sometimes alleged.

Supervision and management costs per dwelling were also "explained" to some extent by the new variables related to site density and direct labour, as indicated in the equation in the previous sub-section on *Type of Authority*. It turns out that, in the aggregate equation using dummy variables, population density is replaced by site density as an effective explanatory variable. Since Supervision and Management costs depend to some extent on the current building programme, site density may directly influence costs (through the Architect's and Engineer's Departments); it seems more likely, however, that high site densities reflect high estate densities in general, thus reducing time and costs involved in general management of the stock of dwellings.

The significant negative effect of direct labour content on supervision and management is a curious finding: perhaps the answer lies in the nature of particular authorities, if those who employ direct labour are also for some reason those who spend less on supervision and management. In this context, the significantly negative correlations between direct labour content and social class suggest that the common factor may be one of political attitude.

Finally, the number of houses completed during the year was tried as an independent variable against supervision and management costs, for the reasons indicated above in *Housing Procedure and Assumptions.* This variable surprisingly had a negative coefficient, but was quite insignificant: we can therefore conclude that the current rate of building has no consistent effect on supervision and management costs per dwelling.

IV. LOCAL HEALTH SERVICES

Local health services comprise a number of heterogeneous services on which the expenditure met from rates, general and rate deficiency grants was, on average, about £2 per head during the year 1964–65, both for the county boroughs and the counties. The services included under Local Health Service are: Health Centres, Care of Mothers and Young Children—Day Nurseries, Child Welfare Centres, Mothers and Baby Homes, other expenditure including Maternity Outfits ; Midwifery ; Health Visiting ; Home Nursing ; Vaccination and Immunisation ; Ambulance Services ; Prevention of Illness, Care and After-Care—Mental Health, Tuberculosis, Other ; Domestic Help ; Expenditure as Local Health Authority under other Enactments. Obviously it was not possible to analyse each service separately within the time and resources at our disposal. The services selected for analysis are Ambulance Services and Home Nursing. The reasons for our choice are based firstly on their financial importance in the local health service sector, and secondly on their vulnerability to fewer conceptual and statistical problems than those encountered with the other services.

The following table indicates the financial importance of the major services categorised under Local Health Services.

AVERAGE NET EXPENDITURE FOR 1,000 POPULATION 1964–65

	Average for all County Boroughs		*Average for all counties*	
	£	s.	£	s.
(1) Ambulance Service	352	11	412	19
(2) Domestic Help	256	0	250	0
(3) Home Nursing	204	1	222	13
(4) Midwifery	154	5	170	8
(5) Mental Health—Training Centres	142	6	131	5
(6) Child Welfare Centre	135	18	116	17
(7) Health Visiting	132	13	112	11
(8) Administration	273	2	262	5
Total (1)-(8)	1,550	16	1,678	18
Total for all Local Health Services	2,000	8	1,956	16

(Source: Local Health Service Statistics, I.M.T.A., November 1965).

Ambulance service ranks first. Home Nursing ranks next to Domestic Help which, however, was excluded from our analysis because of the specific conceptual and statistical problems encountered with its analysis.

The published statistics for Domestic Help related to cost per case, but a desirable statistic for our analysis would be cost per visit, because the cost per case could vary tremendously due to the variation in the number of visits per case, especially in Domestic Help where the majority of cases concerned old people, and could go on for very long periods. Besides, recruiting Domestic Help has varied greatly between the Local Authorities not merely because of labour availability but partly as a matter of tradition. Administrative expenditure comprises about 13½ per cent of the total expenditure on local health services: administrative expenditure as a percentage of total expenditure was also considered as another dependent variable for the reasons given below.

Procedure and Assumptions

(1) *Ambulance Service*

For the ambulance service, expenditure per 1,000 population is used as the dependent variable, as published statistics were available only for this variable. Obviously the expenditure per head may vary between the local authorities, not because of the corresponding variation in "efficiency" in provision of the service, but because of the variation in the quality and quantity of the service provided. One could think of a number of variables which could possibly affect the quantity and quality of the ambulance service. Some of the variables which have been suggested and also considered by us to be of importance, for obvious reasons, are:

(1) Age distribution.

(2) Degree of Industrialisation.

(3) Social class.

(4) Rateable value per capita.

(5) Average weekly earnings.

These variables were, therefore, introduced in our analysis as some of the independent variables with the hope that the variation in the expenditure due to the variation in the quality and quantity of the provision of the service would be picked up by these variables, since omitted variables can lead to bias, as explained in section I above.

If the variations in expenditure per head which were due to the variation in the quantity and quality of the service alone, are assumed to be separated out by the introduction of the above-mentioned variables, it remains to analyse only the differences in cost per homogeneous unit of output. But differences in cost per "homogeneous unit" of ambulance service may arise due to several factors. In addition to the scale factors, such as population, other variables which were thought to be important were:

(1) Population Density.

(2) Degree of Population Concentration (percentage of population in urban area was used as a proxy for (2)).

(3) Degree of accessibility to patients. (In the absence of any better readily available alternative, population per mile was used to indicate roughly the inverse of the degree of accessibility to patients, for a given population.)

The above-mentioned variables were therefore introduced into our analysis so that their effects on expenditure per head could be separated from the effects of scale variables, in which we are particularly interested in this study. Reciprocal arrangements exist, however, under which one authority transports another's patients: for example, a county borough, within whose boundaries a hospital is situated, may provide transport to and from the hospital for patients in the surrounding county. The effect of such arrangements on each authority's expenditure on the ambulance service is difficult to estimate, since payment is made for services rendered: but total expenditure on the service may be reduced.

(2) *Home Nursing*

The published statistics for home nursing related only to expenditure per 1,000 population and cost per visit. "Cost per visit" was used as the dependent variable for this study. Expenditure per head of population was not selected for the reason that it may vary not because of the variation in the cost per unit of service but because of the variations in the total units of service provided. The measure of "efficiency", for this study, is cost per unit of service: therefore, it seemed more sensible to choose costs per visit as our dependent variable, when it is available.

A visit, which is used as the unit of service, may not, however, be considered homogeneous. The average "visit" could be of different durations for different local authorities. Again, visits could vary in quality depending upon the training and qualifications of the personnel employed for this service. It is hoped that by introducing variables such as Age Distribution, Social Class, Rateable value per head (the procedure which was also adopted for other services), the variation in costs due to non-homogeneity of the unit of service may be to some extent separated. Again, costs per "homogeneous" unit of service may vary because of several factors. In addition to the scale variables, population and number of visits, some other variables were considered relevant in this respect: Population Density, Population per mile, Average Earnings, and Percentage of Population in Urban Areas were therefore introduced into our analysis.

It has been suggested that the attachment of Local Authority health service staff to general practices would promote "efficiency" in the services provided, but at the same time the scheme of general practitioner attachment could increase the cost of provision of the service. In our particular case of home nursing, the "cost per visit" could increase because a nurse attached to a general practitioner would have to spend more time per visit than she would otherwise in travelling around the city in order to look after the patients of the practitioner to whom she is attached. One would therefore expect the "cost per visit" to vary to some extent between the local authorities because of the variation in the degree of general practitioner attachment, and should introduce the degree of general practitioner attachment as another independent variable in order to isolate its effects on "cost per visit". In our analysis, however, such a variable was not introduced; firstly because the data were not readily available, and secondly because this variable was quantitatively insignificant for the year 1964–65 to which our analysis relates. To quote Anderson and Draper, who recently carried out a survey in this field, "at the end of 1964, 705 (3·4 per cent) local authority nurses, midwives and health visitors were reported to be working in general practice attachment schemes in England and Wales. Although the number of attachments doubled in 1964, only six local health authorities had 20 per cent or more of their staff working in such schemes "*. We do not think, therefore, that our findings are affected in any important way by the neglect of this variable in our analysis of "cost per visit".

(3) *Administrative Expenditure*

It has been suggested by some economists that administrative expenditure as a percentage of total expenditure could provide a measure of efficiency. It has been argued that although administrative expenditure must be incurred in order to be able to provide the services, yet by itself it is largely "unproductive". Therefore, the lower the amount of expenditure on administration relative to total expenditure the higher may be considered the "efficiency" of a local authority in performance of its services: administration is thus considered entirely an input, whose contribution to a given output must be minimised for greatest efficiency. The assumptions required are therefore:

(*a*) administrative expenditure is uncorrelated with the "quality" or "standard" of service provided;

(*b*) administrative expenditure confers no direct benefits;

(*c*) other inputs are not substituted for administration;

(*d*) the data of such expenditure can be relied on.

It is, of course, not necessary conceptually to make all these assumptions. If one could construct an index of the "standard" of the service provided, it would then be possible to introduce that index as one of the dependent variables, so that the effects, if any, on administration expenditure due to the variation in the "standard" of services provided could be isolated. Similarly, if one could evaluate in monetary terms any benefits conferred by administrative expenditure as "output", administrative expenditures could be calculated net of such benefits: again, it is conceptually possible to obtain reliable data. But what is conceptually possible is not always possible in practice. Of course, none of the above-mentioned assumptions can be accepted in entirety, but, to the extent that one considers that departures from these assumptions are not serious, one may consider this variable a measure of "efficiency".

Administrative expenditure as a percentage of total expenditure may vary between local authorities because of several factors other than scale. In addition to population, used as our scale variable, other variables considered relevant in this respect were again introduced in our analysis of administrative expenditure, so that the effect of the scale variable could be isolated to some extent.

FINDINGS AND EXPLANATIONS

As mentioned above, several variables in addition to population were introduced for the reasons already given. A table of the findings for all the different variables is given in the Appendix. As many independent variables were found to be statistically insignificant in their effects, the omission of such variables from the regression equations was considered

* J. A. D. Anderson and P. A. Draper, The attachment of Local Authority Staff to General Practice, *The Medical Officer*, 3rd March, 1967.

necessary, and the computer was instructed to use only the "best" five independent variables ("best" five in the sense that the explanatory value of each of them is greater than each of those left out).

Ambulances

Regression equations describing the expenditure on the *ambulance service per 1,000 population* with the "best" five independent variables, are given below.

For the County Boroughs:

	Constant	Population	$(Population)^2$	Population per mile	RV per capita	Average Earnings
β	1,038·12	−0·000442	0·000419	0·044172	−0·634831	−2·28415
t		−3·1011	2·8146	0·6801	−0·6492	−2·1031

$R^2=0 \cdot 1705$

For the County Councils:

	Constant	$(Population)^2$	Population Density	RV per capita	Per cent 65+ age	Per cent Urban Population
β	322·399	0·000000976	−41·5634	1·01621	−1·47177	1·56827
t		0·7440	−1·2880	0·6844	−0·4263	2·1109

$R^2=0 \cdot 1512$

(*a*) *Population*

For the county boroughs, *population* (the only scale variable used for an analysis of this service) was found to have a U-shaped relationship to expenditure on the ambulance service, the observed relationship being significant at the 1 per cent level of significance. The calculated turning-point was found to be at about a 50,000 population size, but, as all the county boroughs (except Canterbury with a population of about 32,000) had a population of more than 50,000, the only conclusion which can be derived from this finding is that diseconomies of scale operate significantly for the county boroughs' ambulance service. For the county councils also there is some indication of diseconomies of scale, but the evidence is rather weak, perhaps because of the reciprocal arrangements, discussed above, under which county boroughs do some carrying for the neighbouring counties.

(*b*) *Population Density*

It has been suggested that local authorities with a higher population density would save relatively on carrying costs and that authorities with a lower population density would need to spend more on such costs incurred in providing an ambulance service. But this variable, which was considered important on *a priori* grounds, disappears totally from the equation using the "best" five variables for the county boroughs. For counties, expenditure on the ambulance service seems to vary inversely with the population density; but even in their case, the evidence is rather too weak to reject the corresponding null hypothesis.

(*c*) *Average Earning and Percentage Urban Population*

Our findings here are that "average earnings" and "percentage urban population" significantly affect expenditure on the ambulance service for county boroughs and counties respectively. One plausible explanation might be that people with higher income or earnings possibly use the free ambulance service less frequently than people with a lower income.

Urban population as a percentage of total population was used as a proxy variable for the degree of population concentration. One would think that the greater the degree of concentration the less would be the cost of carrying patients. It is, therefore, puzzling to observe a significantly positive relationship between percentage urban population and expenditure on ambulance service per head. Percentage urban population was perhaps not a good proxy variable for the degree of population concentration, and the greater need and awareness of urban people of the availability of the free service could be contributing factors to this finding.

Other variables were found to have a t-value less than 1, and, therefore, may be completely ignored.

Home Nursing

Regression equations for " cost per visit " with the " best " five independent variables are:

For the County Boroughs:

	Constant	*Population*	*Population Density*	*Population per mile*	*RV per capita*	*Number of visits*
β	5·1953	0·0000162	−0·009779	0·003094	0·052565	−0·00003224
t		3·8914	−2·51669	2·2550	2·7293	4·3278

$R^2=0\cdot3791$

For the Counties:

	Constant	*Population per mile*	*RV per capita*	*Average Earnings*	*Social Class*	*Per cent Urban Population*
β	−0·15656	−0·00548	−0·06399	0·10835	−9·37723	0·078816
t		−1·1622	−0·9435	2·7468	−0·7361	0·7001

$R^2=0\cdot2464$

As was observed for the ambulance service, if population is used as scale variable significant diseconomies of scale are found for home nursing in the case of county boroughs. For the counties the population effect was found to be totally insignificant for " cost per visit ", and, therefore, may be ignored.

Although population was used as a scale variable, it may be argued that the proper scale variable for " cost per visit " is the total number of visits. If the latter is considered *the* relevant scale variable, our findings suggest significant economies of scale in the case of county boroughs.

The other significant variables in the case of county boroughs are: population density, population per mile, and rateable value per capita. For the significant effects of population density and rateable value, the explanations given for their effects on other services (see Ambulances and Housing respectively) apply equally in the case of " cost per visit ". As population per mile indicates roughly the degree of inaccessibility of patients (e.g. through greater congestion on roads), its significant positive effect on " cost per visit " seems sensible.

For the County Councils all variables, except "average weekly earning", were found to be statistically insignificant in their effects on cost per visit. One explanation of the significantly positive association of average earnings with the "cost per visit" could be that the wages and salaries of the personnel employed in home nursing are possibly associated with our average weekly earnings variable.

Administrative Expenditures on Local Health Service

Regression equation for administrative expenditure as a percentage of total expenditure on local health service with the "best" five independent variable in the case of county councils is:

	Constant	*Population*	*(Population)²*	*RV per capita*	*Average Earnings*	*Age*
β	0·53669	−0·000012338	0·0000004303	0·147623	−0·12461	−0·26678
t		−4·4710	3·4779	2·0057	−2·3518	−2·1013

$R^2 = 0 \cdot 4654$

The similar equation for the county boroughs is:

	Constant	*Population*	*Population Density*	*Population per mile*	*RV per capita*	*Average Earnings*
β	6·84263	−0·00000619	0·0905936	−0·00011296	0·0077537	0·015396
t		−2·9359	1·1467	−0·0383	2·0940	0·3712

$R^2 = 0 \cdot 1498$

Our findings for the counties thus suggest a U-shaped curve for administration expenditure with relation to population. Economies of scale operate with an increase in population size until about 1,388,000 population size is reached, when administrative expenditure as a percentage of total expenditures is at its minimum. An expansion of population size beyond that limit might lead to diseconomies of scale. It may, however, be pointed out that only five counties had a population beyond 1,388,000, and, therefore, the evidence of increasing costs beyond that limit is rather weak: the curve could well be asymptotic beyond that population size. Our finding for the county boroughs is perfectly compatible with that of counties, in this respect: for the county boroughs, significant linear economies of scale were found to operate for administrative expenditure.

Another significant variable, for both the counties and county boroughs, was rateable value per capita, which had a significant positive effect on administrative expenditure. As was discussed above, rateable value is the only tax base for the local authorities, and the larger the tax base the larger the amount they could afford to spend on administration. This could be the explanation of the significant positive relationship between rateable value and administrative expenditure.

No other variables were found to have significant effects on administration for county boroughs. For the counties, however, two other variables, Average weekly earning and "Age", were found to have surprisingly significant negative effects: on the whole, no significant effects were expected from these variables.

V. HIGHWAYS

Procedure and Assumptions

The principal statistics of interest which were readily available related to expenditure on Maintenance and Minor Improvements. The data, covering the years 1964–65 and 1965–66, allowed us to construct figures on expenditure per mile on maintenance and minor improvements for each class of road for the *counties*. Thus, the dependent variables analysed in the case of the counties are:

(1) Total expenditure on MMI per mile of *all types of road.*

(2) Expenditure on MMI per mile of *Trunk Road.*

(3) Expenditure on MMI per mile of *Class I Road.*

(4) Expenditure on MMI per mile of *Class II Road.*

(5) Expenditure on MMI per mile of *Class III Road.*

(6) Expenditure on MMI per mile of *Unclassified Road.*

But for other categories of Local Authorities, such a detailed analysis was not possible. For the County boroughs, the non-county boroughs and the urban districts, the only two dependent variables analysed are:

(1) Total expenditure on MMI per mile of all types of road ; and

(2) Expenditure on MMI per mile of unclassified road.

The reasons for not doing a separate analysis for each of the other classes of road are either that the statistics on expenditure and mileage for other types of road are very unreliable and/or that the figures are quantitatively unimportant. A substantially large percentage of total expenditure on MMI is devoted entirely to unclassified roads, for which, therefore, a separate analysis was provided. As the expenditure on highways by Rural Districts is negligible, no separate analysis for them was considered worth pursuing.

There are several problems which arise in treating expenditure per mile on MMI as a measure of efficiency. First, there is a definitional problem. There is no objective criterion to distinguish a " minor " improvement from a " major " one. The problem is similar to the perennial one of distinguishing capital expenditures from current (or that of finding an objective criterion for deciding which items of expenditure should go " above the line " and which " below the line " in a British Budget). Any criterion in this matter is bound to be arbitrary, and is usually dictated by administrative feasibility and convenience. If therefore different local authorities followed very different administrative practice in deciding which improvements are " major " and which " minor ", our dependent variables would be meaningless. However, it seems that the standard of administrative practice does not vary enormously between local authorities. Thus, so long as the variation in practice is not associated with the scale variables, in which we are particularly interested, our analysis of the scale effects should not be very much affected. These arguments apply equally to the similar problem of classification into classes of road.

Secondly, our data relate only to two years. Although MMI expenditure could be regarded as " recurrent ", much of it could easily be deferred for years on particular stretches of road, until the Ministry of Transport

" remind " the authority. An average of MMI expenditure per mile over seven years has been suggested, and would probably be preferable, but the data is not available for a wide range of authorities and roads for that time-span.

Other problems arise because of heterogeneity in the service provided. The statistics do not allow a breakdown of MMI, which is something of a mixed bag; in any case, the distinction between maintenance and minor improvement is itself quite arbitrary (expenditures over £5,000 being minor improvements).

The amount of " upkeep " may itself vary. Firstly, the standards required by authorities may vary, according to financial resources, or to local demand and political pressures: hence the introduction of certain independent variables considered relevant in this respect (e.g. social class, rateable value per capita). Secondly, the same standard of " upkeep " may require different expenditures on MMI per mile depending upon several factors: rates of traffic flow, geological structure, weather conditions, labour costs, on-site delivery costs of road-making materials, etc. Unfortunately, data for most of these variables were not available on a national scale; and, therefore, it was not possible to introduce them in our analysis. Some indices of traffic flows (total flow of traffic per mile and per unit area, heavy vehicle flow per mile and per unit area) were, however, available for counties only. These were calculated on the basis of a small sample of different sections of different classes of roads. Although such figures do not relate to any particular type of road, in the absence of any better alternative they were used also for our analysis of the expenditure on different classes of roads, assuming that the differences between flows for different types of road do not vary greatly between local authorities. Further, as separate flow figures were not available for county boroughs, non-county boroughs and urban districts, the respective flow figures for the county were used as proxies, depending upon the location of the authority. This can to some extent be justified by interdependence of rates of flow within an area : since rates of flow within areas are more interdependent the closer the areas are to each other, our use of flow data relating to the county may quite well indicate dissimilarities in traffic flow among authorities in different counties.

For some counties (a total of thirty) figures of labour costs as a percentage of total expenditure incurred directly by a county were available, and, therefore, this was introduced in a separate analysis for these counties in order to assess its effect, if any, on total expenditure per mile; unfortunately, for other local authorities no such figures were available. Statistics of average earnings in different regions were used as proxies for labour costs for the other local authorities.

Lastly, the cost of a unit of " upkeep " of highways may vary, even when allowance is made for all the above-mentioned factors, not only because of the scale factors (population and total mileage), but also because of differences in the degree of mechanisation, the extent to which a local authority uses hired plant as against its own plant, etc. To separate the effects of these factors on " efficiency ", we have introduced the variables K'/L' (expenditure on own plant use as a ratio of expenditure incurred on direct labour), K''/L'' (expenditure on own plant and on hired plant as a ratio of total estimated expenditure on labour), and percentage of hired plant.

The tables of the findings for all the variables introduced in our analysis of highways are in the appendix. Regression equations calculated only with the five " best " dependent variables are quoted in the text.

Total expenditure per mile

Regression equations for total expenditure per mile with the " best " five variables are:

For the County Councils:

	Constant	*(Population)²*	*Population per mile*	*Average Earnings*	*Total Mileage*	*Heavy V per mile*
β . .	−001·5936	0·00000698	1·2953	7·5426	−0·031891	−0·085498
t . .		1·3456	4·2363	2·7234	−1·3108	−1·7995
			$R^2=0\cdot8240$			

For the County Boroughs:

	Constant	*Population*	*(Population)²*	*Population per mile*	*RV per capita*	*Total Mileage*
β .	0·036832	0·001889	−0·0009104	0·28419	5·82232	−0·958526
t .		1·5963	−1·5283	1·0746	1·8099	1·3993
			$R^2=0\cdot1482$			

For the Non-County Boroughs:

	Constant	*Population*	*Population Density*	*Population per mile*	*Average Earnings*	*Heavy V per mile*
β .	−0·025846	−0·0019963	7·6766	0·463519	1·91030	−0·027922
t .		1·9506	1·1658	2·8563	1·2851	1·1716
			$R^2=0\cdot1482$			

Total expenditure per mile was used as an overall index of " efficiency ". For the non-county boroughs, our findings suggest significant economies of scale, population being used as a scale variable. For the county boroughs, our findings rather suggest an inverted U-shaped relationship, i.e., diseconomies of scale operate with an increase in the population size until about 104,000 population size is reached, expansion beyond which could lead to economies of scale. However, as the mean population of the county boroughs was about 186,000, for a large majority of these local authorities economies of scale operate. For the urban district councils and the counties (see the table given in the appendix for the appropriate regression equation which uses population as the only scale variable), population had a U-shaped relationship to total expenditure per mile, but at a level of significance of more than 10 per cent. The turning points were calculated to be at populations of around 950,000 and 4,000 for the counties and urban districts respectively. For the county councils, since their mean population was 510,000, and bearing in mind the low level of confidence, all one can say is that there is some evidence of economies of scale up to around a population of 950,000, and that diseconomies of scale may obtain beyond that point (or the curve could as well be asymptotic beyond that population size, since only seven counties had a population more than 950,000). But, for the urban districts, as the turning point was found to be around a small population size of 4,000, and again bearing in mind the low level of significance, one can suggest that diseconomies of scale possibly operate in their case.

If, however, one chooses total mileage as the relevant scale variable, our findings suggest some economies of scale for the county boroughs and the counties, but the evidence is rather weak (level of significance more than 10 per cent).

Population per mile seems to have a positive effect on expenditure per mile. In the case of counties, non-county boroughs and urban districts, a statistically significant (at the 1 per cent level of significance) positive effect was found. One explanation could be that high population per mile indicates high traffic flow (other things being equal) and hence high maintenance activity. Its significant positive effect could also arise due to its effects on grants received by a local authority, population per mile being one of the factors taken into account in determining the total amount of grants made to a local authority.

Average earnings had a positive effect on expenditure per mile for all the different categories of local authorities. For the counties, its positive effect was significant at the 1 per cent level of significance. Insofar as higher earnings suggest higher wages and salaries costs, and maintenance and minor improvement of highways being quite a labour-intensive service, one would expect such a finding.

As one would expect, rateable value per capita, being the tax-base for the local authorities, had a consistently positive effect on expenditure per mile (significant at the 10 per cent level of significance for the county boroughs); whereas heavy vehicle flow per mile had surprisingly negative effects for the different categories of local authorities (at the 10 per cent level of significance for the counties only). The variable, percentage of trunk, Class I and Class II roads, used as an index of the overall class of road in a local authority, again had a surprisingly significant negative effect on expenditure for the urban districts (see the relevant table in the Appendix).

Expenditure per mile—Unclassified Roads

Regression equations for expenditure per mile on unclassified roads with the " best " five variables are:

For the County Boroughs:

	Constant	*Population per mile*	*RV per capita*	*Average Earning*	*Traffic flow per mile*	*Heavy V flow per mile*
β . .	−0·09721	−0·33783	4·62379	4·23704	−0·01033	0·027498
t . .		1·9312	1·5458	1·3349	−0·9829	0·8066
			$R^2=0\cdot1784$			

For the Non-County Boroughs:

	Constant	*(Population)*^{3}	*Population per mile*	*RV per capita*	*Heavy V flow per area*	*Heavy V flow per mile*
β . .	196·2015	−0·025744	0·55978	3·0521	1·8426	−0·063158
t . .		−2·4233	3·8964	1·7537	1·3295	−1·5535
			$R^2=0\cdot1377$			

" Best " equations for other local authorities were not calculated: therefore, the equations incorporating all variables, given in the Appendix, should be referred to particularly for expenditure on unclassified roads by the counties and urban districts.

Population again had a significant negative effect on expenditure per mile of unclassified roads for non-county boroughs, for which our findings suggest economies of scale at an increasing rate with increasing population size. No significant population effect, however, was found for other categories of local authorities.

If total mileage is considered the relevant scale variable, our findings suggest a U-shaped relationship between total mileage and expenditure on unclassified roads for the county councils only. The turning point was calculated to be at a total mileage of around 4,000, but, as both total mileage and total mileage squared had t-values around one, the evidence with regard to the effect of total mileage on expenditure per mile of unclassified road may be considered rather weak. For other local authorities, with t-values less than one, the effect of total mileage may be considered negligible.

Population per mile, as in the case of total expenditure per mile discussed above, was found to have a positive effect on expenditure per mile of unclassified roads (significant at about the 5 per cent level of significance for county boroughs, non-county boroughs and urban districts). Average earnings was also found to have a positive effect, with a t-value around one for county boroughs and urban district councils. Rateable value per head had a significant positive effect (at the 10 per cent level of significance) for county boroughs and non-county boroughs. We have already explained above (see statistical findings and explanations for total expenditure per mile) why on *a priori* grounds one would expect such findings for the variables discussed in this paragraph.

Social Class was also found to have a positive effect (significant at the 10 per cent and 5 per cent levels of significance for non-county boroughs and urban districts respectively) on expenditure on unclassified roads. As argued above, the " Social class " variable is likely to affect the quantity and quality of a service provided by a local authority: the higher the index of social class for a local authority, the larger the amount of expenditure one would expect by that local authority.

Traffic flow variables and other variables introduced in our analysis were found to be statistically insignificant in their effects on expenditure per mile of unclassified roads for all the different categories of local authorities, and, therefore, may be ignored for explanatory purposes.

Other types of Highways in County Councils

Regression equations for expenditure per mile, for different classes of road in county councils, with the " best " five variables are:

For expenditure per mile on *Trunk Roads:*

	Constant	*Population*	*Population per mile*	*RV per capita*	*Social Class*	*Trunk Road Mileage*
β .	382·9377	−0·002827	4·0529	0·88117	−0·00011201	10·07801
t .		−2·1180	1·5399	2·9168	−1·8792	2·1283

$R^2=0\cdot3243$

For expenditure per mile on *Class I Roads:*

	Constant	*Population*	*Population per mile*	*Class I total mileage*	*Traffic flow per mile*	*Heavy V flow per area*
β . .	1,785·369	0·002851	−1·58921	−5·2292	0·22659	−32·6186
t . .		5·30803	−1·3630	−4·8628	2·6590	−3·7791

$R^2=0{\cdot}8382$

For expenditure per mile on *Class II Roads:*

	Constant	*(Population)*^{2}	*Population Density*	*Population per mile*	*Social Class*	*Heavy V flow per mile*
β .	−25·6337	0·000034678	1,294·164	−1·2031	2,319·897	−0·146766
t .		4·9712	5·9175	−1·6546	2·29383	−2·1185

$R^2=0{\cdot}9169$

Population had a significant negative effect on trunk road expenditure per mile, suggesting economies of scale. For the Class I and Class II roads, however, population had a significant positive effect, suggesting diseconomies of scale. (The equation given in the Appendix for Class I roads, in which population squared was introduced but the other scale variable, total mileage of Class I road, and heavy vehicle flow per unit area were excluded also suggest diseconomies of scale for counties with a population of more than 630,000.) For Class III roads (see the relevant table in the Appendix), our findings again suggest largely diseconomies of scale, as most of the counties had a population of more than 185,000, beyond which diseconomies of scale operate. It is, therefore, difficult to draw any conclusion about the overall effect of population. It is worth repeating here that for our overall index, total expenditure per mile of all types of road, discussed above, we found that economies of scale operate with an increase in the population size until about 950,000 population is reached. Expansion of the size of a county beyond that size could lead to increasing cost per overall unit of highway MMI.

The other scale variable used was the total mileage of all types of road. When it was regressed with a set of variables excluding specifically population, it did not show any significant effect on expenditure per mile of either trunk, Class I or Class II road. However, with a different set of variables, in the regression equations (quoted above) which were computed by using only the five "best" variables, total mileage showed a significant negative effect (i.e. economies of scale) on expenditure on Class I roads, whereas the opposite effect was found for trunk roads in the counties. It is difficult to interpret such contrasted findings.

For trunk roads, both population per mile and rateable value per head had significant positive effects, possibly for the reasons already suggested. Social class, however, had a significant negative effect on expenditure on trunk roads, whereas it had a positive effect on expenditure on class II roads. The inhabitants within a local authority use the secondary roads more often than the trunk roads, which have higher spillover benefits. Greater awareness in "higher" social class areas of spillover benefits of trunk roads could perhaps encourage substitution of expenditure on trunk roads for expenditure on secondary roads.

Traffic flow per mile and population density had significant positive effects on expenditure on class I and class II roads respectively. Both variables affect the wear and tear of the roads, and, therefore, one would expect their effects on expenditure on roads to be positive. Population per mile was found to have a positive effect on trunk road expenditure, but a surprisingly negative effect on class I and class II road expenditures. These effects, however, were not highly significant, and the surprising negative effect of population per mile could be due to the effects of traffic flows being more effectively picked up by the other variables, traffic flow per mile and population density, for these types of roads. The effects of heavy vehicle flow per mile and area were again surprisingly found to be negative for class II and class I roads.

Effects of Mechanisation and Percentage of Hired Plant

As mentioned above, it was possible to introduce a few other variables, K'/L' ; K''/L'' ; per cent labour costs ; per cent hired plant etc., for some counties ($N=30$). The table showing the effects of these variables on total expenditure per mile for the subset of counties is given in the Appendix. Both percentage labour and K'/L' were found to affect total expenditure per mile significantly (at a level of significance of 5 per cent). Our findings suggest that the lower the labour cost as a percentage of total cost, the lower the expenditure per mile ; and the higher the expenditure on own plant use as a ratio of direct labour cost, the lower the expenditure per mile. As both the variables roughly indicate the degree of mechanisation, one can say that mechanisation had a positive effect on " efficiency ". The variable percentage of hired plant was found to have a positive effect on expenditure per mile, suggesting that it may be more economic to buy plant than to hire, but, as the t-value for this variable was around 1·25, the evidence for its positive effect is rather weak.

Summary Chart Showing Existence of Economies (Diseconomies) of Scale[1]

Service	Scale Variable	Dependent Variable	County Councils	County Boroughs	Non-County Boroughs	Urban District Councils	Rural District Councils
Housing[5]	I. Population	(a) Cost per foot super . .	—	Diseconomies	Diseconomies[2]	Zero Effect	Diseconomies[2]
		(b) Supervision and Management	—	Zero Effect	Diseconomies	Economies[3]	Diseconomies
	II. Total Stock of Dwellings	(a) Cost per foot super . .	—	Zero Effect	Zero Effect	Economies	Zero Effect
		(b) Supervision and Management	—	—	Economies	Economies	Zero Effect[4]
Highways	I. Population	(a) Total Expenditure per mile .	Economies[7]	Economies[6]	Economies	Diseconomies[8]	—
		(b) Unclassified Road Expenditure per mile . . .	Zero Effect	Zero Effect	Economies	Zero Effect	—
	II. Total Mileage	(a) Total Expenditure per mile .	Economies[9]	Economies[9]	Zero Effect	—	—
		(b) Unclassified Road Expenditure per mile[2] . . .	Economies[10]	Zero Effect	Zero Effect	Zero Effect	—
Health Services	I. Population	(a) Cost of Ambulance Service [per 1,000] . . .	Zero Effect[11]	Diseconomies[12]	—	—	—
		(b) Per cent. Administration Costs	Economies[13]	Economies	—	—	—
		(c) Cost per Visit (Home Nursing)	Zero Effect	Diseconomies	—	—	—
	II. Total Number of Visits .	Cost per Visit (Home Nursing) .	Zero Effect	Economies	—	—	—

1. If a scale variable has a regression coefficient with a t-value less than 1, its effect on the dependent variable is considered to be zero. The chart does not show t-values and levels of significance, as these can be found in the Appendix tables. Equations with " best " five independent variables and t-values of corresponding regression coefficients are included in the text. The purpose of the chart is to provide a broad picture of the scale effects on our dependent variables.

2. Inverted U-shaped relationship. Diseconomies operate up to a population size of 60,000, when cost per foot super is at a maximum. Beyond this point, costs might diminish, but the inverted U-shape is inconsistent with the notion of an " optimum " population size for a local authority. Furthermore, for R.D.C.'s, only twelve out of the sample of one hundred had a population greater than 60,000, and the curve beyond this point might well be asymptotic. For N.C.B.'s, 20 out of 89 in the sample had populations greater than 60,000. Because of the inverted U-shape relationship a reduction of cost could be achieved not only by increasing the size beyond 60,000 but also by reducing to below 60,000.

3. This was a U-shaped relationship, costs of supervision and management being at a minimum for population size of about 40,000. The mean size of population for U.D.C.'s, was just less than 33,000.

4. This finding takes account of the serious underestimation of supervision and management costs for smaller R.D.C.'s. We therefore disregard the finding of apparent diseconomies of scale.

5. Other scale variables—number of houses completed and product of 1d. rate—were tried. For " number of houses completed ", except for the sub-group of Non-County Boroughs (N=23), any hypothesis suggesting economies of scale, with regard to cost per foot super, was rejected. Findings suggested a positive effect of " 1d. rate " on cost per foot super for C.B.'s and R.D.C.'s.

6. Inverted U-shaped relationship. Diseconomies up to population size of 104,000 and expansion of population beyond this point would probably lead to economies; however, there would be no minimum point. The mean population for C.B.'s was around 186,000.

7. U-shaped relationship. Turning-point being around 950,000, and county councils having a mean population of about 510,000, there is some evidence of economies; and the curve could be asymptotic beyond 950,000.

8. U-shaped relationship. As the turning-point is 4,000, bearing in mind the low significance-level, this is some evidence that diseconomies operate. Mean population around 33,000.

9. For scale effects for other categories of Highways in County Councils, see text and Appendix table.

10. U-shaped relationship with turning-point at around 4,000 miles. However, the evidence is rather weak; as both total mileage and total mileage squared, have t-values around 1. Average mileage is 2,260.

11. For the counties there is weak evidence (t-value less than 1) of diseconomies of scale, possibly because of reciprocal arrangements discussed in the text.

12. U-shaped relationship with turning-point of about 50,000 population. But as all C.B.'s, except one, have a population greater than this, the conclusion must be that diseconomies operate significantly.

13. Significant economies, up to populations of 1,388,000, but as only five counties have populations greater than this, the evidence of increasing costs beyond this limit is rather weak—the curve could equally well be asymptotic.

APPENDIX

VARIABLES IN HOUSING EQUATIONS

(1) Population	I.M.T.A. Housing Statistics, 1964–65
(2) Population squared(*a*)	I.M.T.A. Housing Statistics, 1964–65
(3) Total number of dwellings completed during the year	I.M.T.A. Housing Statistics, 1964–65
(4) Cost of construction per foot super of 3-bedroom houses	I.M.T.A. Housing Statistics, 1964–65
(5) Product of 1d. rate	I.M.T.A. Housing Statistics, 1964–65
(6) Rateable value per head	I.M.T.A. Housing Statistics, 1964–65
(7) Supervision and management (general) expenditure per dwelling	I.M.T.A. Housing Statistics, 1964–65
(8) Rate subsidy as per cent of total revenue on housing account	I.M.T.A. Housing Statistics, 1964–65
(9) Population density per acre	I.M.T.A. Return of Rates, 1964–65
(10) Rate and grant borne expenditure on housing	I.M.T.A. Housing Statistics, 1964–65
(11) Total stock of authority dwellings ...	I.M.T.A. Housing Statistics, 1964–65
(12) Average weekly earnings (excluding overtime premium) of Builders' Labourers and other engineering operatives	Statistics on Incomes, Prices, Employment and Production, December, 1965, Table 13B
(13) Social Class Index (per cent in socio-economic categories I and II) (*b*)	Census, 1961
(14) Average Site Density ... ... (15) Average Number of Dwellings per site (16) Percentage of direct labour	From data provided by the Ministry of Housing Statistics Division
(17) Population Growth 1931–1951 ...	*British Towns*, C. A. Moser and Wolf Scott (Oliver and Boyd, 1961). Second principal component distinguished.
(18) County Borough *versus* Non-County Borough (19) Non-County Borough *versus* Urban District Council (20) Urban District Council *versus* Rural District Council	Dummy Variables

Notes:

(*a*) In the summary tables of Housing Analysis, N.B. the figures for population squared have been scaled in millions.

(*b*) For the separate analyses of County Boroughs and the 23 Non-County Boroughs, the social class index used was the first principal component distinguished in Moser and Scott (*op. cit.*).

VARIABLES IN COUNTY COUNCILS HIGHWAYS EQUATIONS

(1) Population	I.M.T.A. Housing Statistics, 1964–65
(2) Population squared	I.M.T.A. Housing Statistics, 1964–65
(3) Population density per acre	I.M.T.A. Return of Rates, 1964–65
(4) Population per mile	Society of County Treasurers Highways Expenditure, 1964–65
(5) Product of 1d. Rate	I.M.T.A. Housing Statistics, 1964–65
(6) Rateable Value per capita	I.M.T.A. Housing Statistics, 1964–65
(7) Industrial Rateable Value divided by total Rateable Value	Financial and General Statistics of County Councils 1964–65
(8) Average Earnings (weekly; excluding overtime premium) of Builder's Labourers and other engineering operatives	Statistics of Incomes, Prices, Employment and Production, December, 1965, Table 13B
(9) Social Class index (per cent in socio-economic categories I and II)	Census 1961

(10) Expenditure per mile on Trunk Roads (11) Expenditure per mile on Class I Roads (12) Expenditure per mile on Class II Roads (13) Expenditure per mile on Class III Roads (14) Expenditure per mile on Unclassified Roads (15) Expenditure per mile on Total road mileages	Calculated from statistics received from the Ministry of Transport Statistics Division
(16) Mileage of Trunk Roads ... ... (17) Mileage of Class I Roads ... ... (18) Mileage of Class II Roads ... ... (19) Mileage of Class III Roads ... ... (20) Mileage of Unclassified Roads ... (21) Mileage of Total Roads	Statistics received from the Ministry of Transport Statistics Division
(22) Flow per mile (area index)	$\Sigma_s \left(\frac{A}{B \times D}\right)_s (D)_s \div \Sigma_s D_s$
(23) Flow per mile	$\Sigma_s \left(\frac{A}{D}\right)_s (D)_s \div \Sigma_s D_s$
(24) Heavy vehicle flow per mile (area index)	$\Sigma_s \left(\frac{A \times C}{B \times D}\right)_s (D)_s \div \Sigma_s D_s$
(25) Heavy vehicle flow per mile	$\Sigma_s \left(\frac{A \times C}{D}\right)_s (D)_s \div \Sigma_s D_s$

Notes:

(*a*) Variables 22 through 25 were from statistics provided by the Ministry of Transport—Economic General Division.

(*b*) The difference between variables 22 and 23 and between 24 and 25 is that 22 and 24 take the *width* of road into account, whereas 23 and 25 are straight averages per mile.

(*c*)

Code	*Data*
A	7-day average August Census flow.
B	Width of road in feet.
C	Per cent of heavy goods vehicles.
D	Length of section(s) in miles.

(26) $\frac{K'}{L'}$ ... ... Authority owned plant running costs, divided by Authority labour costs.

(27) $\frac{K''}{L''}$ ... ... Authority owned plant plus hired plant running costs, divided by the appropriate labour costs. N.B., estimates of labour costs in hired plant were calculated on the basis of authority labour costs plus 12 per cent for profit.

(28) Per cent Cost of Hired Plant.
(29) Per cent Labour Cost.

Note:

Variables 26 through 29 from basic data provided through the Ministry of Transport F.H.A.6.

Variables in County Boroughs, Non-County Boroughs, and Urban Districts Highways Equations

(1) Population ... ... I.M.T.A. Housing Statistics, 1964–65
(2) Population squared ... ... I.M.T.A. Housing Statistics, 1964–65
(3) Population density per acre ... ... I.M.T.A. Return of Rates, 1964–65
(4) Population per mile ... ... Society of County Treasurers Highways Expenditure, 1964–65

(5) Product of 1d. Rate . . .	I.M.T.A. Housing Statistics, 1964–65
(6) Rateable Value per capita . .	I.M.T.A. Housing Statistics, 1964–65
(7) Average earnings (weekly; excluding overtime premium) of Builders, Labourers and other engineering operatives	Statistics of Incomes, Prices, Employment and Production, December, 1965, Table 13B.
(8) Social Class Index (per cent in socio-economic categories I and II)	Census 1961.
(9) Expenditure per mile on unclassified roads	Variables 9 through 13 were obtained from statistics provided by the Ministry of Transport Statistics Division.
(10) Expenditure per mile on total roads .	
(11) Mileage of unclassified roads . .	
(12) Mileage of unclassified total roads .	
(13) Per cent mileages of Classes I and II Roads over total roads	
(14) Flow per mile (area index) . .	$\Sigma_s \left(\frac{A}{B \times D}\right)_s (D)_s \div \Sigma_s D_s$
(15) Flow per mile	$\Sigma_s \left(\frac{A}{D}\right)_s (D)_s \div \Sigma_s D_s$
(16) Heavy vehicle flow per mile (as in 14).	$\Sigma_s \left(\frac{A \times C}{B \times D}\right)_s (D)_s \div D_s \Sigma_s$
(17) Heavy vehicle flow . . .	$\Sigma_s \left(\frac{A \times C}{D}\right)_s (D)_s \div \Sigma_s D_s$

Notes:

(*a*) Variables 14 through 17 were from statistics provided by the Ministry of Transport—Economic General Division.

(*b*) The difference between variables 14 and 15 and between variables 16 and 17 is that 14 and 16 take the *width* of road into account whereas 15 and 17 are straight averages per mile.

(*c*) *Code*	*Data*
A	7-day average August Census flow.
B	Width of road in feet.
C	Per cent. of heavy goods vehicles.
D	Length of section (s) in miles.

Variables in County Councils Health and Welfare Equations

Variables 1 through 9 are the same ([a]) as for the County Councils Highways Equations

(10) Proportion of Population older than 65 years	I.M.T.A. Welfare Service Statistics, 1964–65
(11) Percentage Population in urban Districts	I.M.T.A. Police Force Statistics, 1964–65
(12) Percentage area in Urban Districts .	I.M.T.A. Police Force Statistics, 1964–65
(13) Percentage Administration to Total Costs	I.M.T.A. Local Health Services Statistics, 1964–65
(14) Home Nursing—number of visits .	I.M.T.A. Local Health Services Statistics, 1964–65
(15) Home Nursing—cost per visit (total in shillings)	I.M.T.A. Local Health Services Statistics, 1964–65
(16) Ambulance Service—Net Expenditure per 1,000 of the population (in pounds £)	I.M.T.A. Local Health Services Statistics, 1964–65

Variables in County Boroughs Health and Welfare Equations

Variables 1 through 8 are the same as for County Boroughs Highways Equations

(9) Proportion of Population older than 65 years	I.M.T.A. Welfare Service Statistics, 1964–65
(10) Percentage of Administration to Total Costs	I.M.T.A. Local Health Service Statistics, 1964–65

([a]) Population squared is scaled in 100,000's, instead of in 1,000,000's.

(11) Home Nursing—number of visits .	I.M.T.A. Local Health Service Statistics, 1964–65
(12) Home Nursing—cost per visit (total in shillings)	I.M.T.A. Local Health Service Statistics, 1964–65
(13) Ambulance Service — Net Expenditure per 1,000 of the population (in pounds £)	I.M.T.A. Local Health Service Statistics, 1964–65

Independent Variables	County Boroughs n=61			Non County Boroughs n=23			Non County Boroughs n=89			Urban Districts n=82			Rural Districts n=100		
	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2
Dependent Variable=Cost per foot super															
Population (excluding Population²)*	0·0000067	1·31647		−0·00012	−0·91369		0·000019	0·44959		−0·000019	−0·48431		0·000049	1·14492	
Population	0·00001728	1·2024	0·0219	0·00081	0·76115	0·0213	0·000208	1·54899	0·0018	0·000006	0·04339	0·0024	0·00018	1·42767	0·0124
(Population)²	−0·00001127	−0·7871	0·0079	−0·00564	−0·86900	0·0196	−0·001732	−1·48172	0·0188	−0·000234	−0·20212	0·0004	−0·00148	−1·16698	0·0116
Population Density	0·1921	1·0379	0·0137	0·51185	1·74584	0·0790	0·479213	2·81427	0·0679	0·41259	2·43724	0·0539	−1·32419	−1·02617	0·0099
Social Class	0·00715	1·9832	0·0502	0·02153	3·70021	0·3551	0·59249	3·33160	0·0951	0·24392	2·35223	0·0502	0·20491	2·42333	0·0556
Population Growth	0·00266	0·5173	0·0034	0·00957	0·85180	0·0188									
Rate Subsidy Percentage	0·41000	3·3053	0·1393	0·00197	0·00574	0·0000	−0·13465	−0·76995	0·0051	−0·20549	−1·50653	0·0206	−0·09050	−0·37820	0·0014
Average weekly earnings	0·14660	1·4455	0·0266	0·00258	0·01855	0·0000	0·00933	0·14322	0·0002	0·21742	3·42151	0·1062	−0·06767	−1·38835	0·0182
Rateable value per head	0·12500	0·0872	0·0001	−0·01219	−0·09837	0·0002	0·054919	0·83975	0·0060	−0·1089	−0·18533	0·0003	−0·06574	−1·17884	0·0132
	α=0·75103	R=0·580398		α=15·4137	R=0·79806		α=24·8388	R=0·55297		α=−18·9736	R=0·57352		α=59·682	R=0·35905	
Dependent Variable=Supervision and Management Cost															
Population (excluding Population²)*	−0·0000003	−0·33528		0·000017	0·96786		0·000010	1·60759		0·0000123	1·47413		0·0000182	2·346795	
Population	0·0000004	0·1396	0·0012	0·000122	0·78060	0·0174	−0·000004	−0·20227	0·0062	−0·000037	−1·39153	0·0159	0·000026	1·14269	0·0463
(Population)²	−0·0000007	−0·2760	0·0008	−0·00065	−0·67766	0·0089	0·000129	0·74229	0·0035	0·000462	1·951616	0·0269	−0·000093	−0·38025	0·0012
Population Density	0·04538	1·3567	0·0194	0·08372	1·92962	0·0718	0·061154	2·41801	0·0368	0·01238	0·35834	0·0009	−0·46335	−1·95643	0·0324
Social Class	0·003159	4·8488	0·2476	0·00353	4·09785	0·3240	0·14042	5·31614	0·1778	0·10129	4·78748	0·1618	0·04592	2·95903	0·0734
Population Growth	0·000203	0·2185	0·0005	0·00147	0·88311	0·0151									
Rate Subsidy Percentage	0·006154	0·2745	0·0008	0·03900	0·76573	0·0113	0·02988	1·15035	0·0083	0·058045	2·08569	0·0307	−0·02859	−0·65130	0·0036
Average weekly earnings	0·028406	1·5492	0·0253	0·00868	0·42109	0·0034	0·02487	2·57150	0·0416	0·040287	3·10733	0·0682	0·00496	0·55497	0·0026
Rateable value per head	0·11245	−0·4329	0·0020	−0·01013	−0·55213	0·0059	−0·01214	−1·25022	0·0098	0·030208	2·51966	0·0448	0·01048	1·02424	0·0089
	α=−2·51055	R=0·67266		α=−3·51347	R=0·85434		α=−4·61981	R=0·70028		α=−8·75487	R=0·69112		α=1·64948	R=0·46966	
Dependent Variable=Rate and Grant-Borne Expenditure per capita on Housing															
Population (excluding Population²)*	−0·000005	−0·65951		−0·000104	−0·92540		−0·00016	−1·90866		−0·00024	−1·96460		−0·00026	−3·05432	
Population	−0·000010	−0·4414	0·0020	0·00135	1·41159	0·0062	−0·00032	−1·17004	0·0181	−0·00034	−0·86818	0·0325	−0·000491	−1·93707	0·0757
(Population)²	0·000005	0·2235	0·0002	−0·00895	−1·53041	0·0156	0·00143	0·60446	0·0028	0·00098	0·27795	0·0007	0·00259	0·96785	0·0076
Population Density	0·859364	2·9358	0·0397	0·32447	1·22686	0·0100	−0·00888	−0·02573	0·0000	0·12341	0·23928	0·0005	6·93235	2·68102	0·0583
Social Class	−0·031127	−5·4596	0·1373	−0·03915	−7·45781	0·3707	−1·50884	−4·18460	0·1360	−1·42977	−4·52586	0·1745	−0·21530	−1·27071	0·0131
Population Growth	−0·011566	−1·4200	0·0093	−0·01964	−1·93728	0·0250									
Rate Subsidy Percentage	1·089519	5·5532	0·1421	1·08265	3·49112	0·0812	1·13273	3·19465	0·0793	1·08508	2·61120	0·0581	1·26420	2·63803	0·0565
Average weekly earnings	−0·246753	−1·5380	0·0109	−0·19582	−1·55875	0·0162	−0·16451	−1·24607	0·0121	−0·22079	−1·14050	0·0111	0·01617	0·16560	0·0002
Rateable value per head	0·310809	1·3675	0·0086	0·23132	2·06841	0·0285	0·29703	2·24011	0·0390	0·04535	0·25334	0·0005	−0·10105	−0·90428	0·0066
	α=76·823718	R=0·87201		α=26·81732	R=0·95222		α=101·2166	R=0·60895		α=117·118	R=0·60778		α=37·72855	R=0·50319	

* The coefficients of population were obtained by omitting (population)² above from each equation. The coefficients of the other variables, and the R's, changed slightly, but these changes are not shown, to economise space.

SUMMARY OF PARTIAL* COEFFICIENTS FOR ADDITIONAL VARIABLES IN HOUSING ANALYSIS

Independent Variable	COUNTY BOROUGHS n=61		NON COUNTY BOROUGHS n=23		NON COUNTY BOROUGHS n=89		URBAN DISTRICTS n=82		RURAL DISTRICTS n=100	
	β	t	β	t	β	t	β	t	β	t
DEPENDENT VARIABLE= COST PER FOOT SUPER										
Total stock of dwellings	0·000050	1·15416	0·00036	0·21630	−0·000466	−0·93504	−0·000653	−1·38095	−0·000404	−0·65317
Product of 1d. rate ...	0·000447	1·56763	−0·00039	−0·77889	0·000089	0·41779	−0·000141	−0·68917	0·00045	1·59875
Number of houses completed	0·000653	0·48676	−0·02658	−1·35176	0·004946	0·680487	0·00383	0·44410	−0·00132	−0·11289
DEPENDENT VARIABLE= SUPERVISION AND MANAGEMENT COST										
Cost per foot super ...	0·049239	2·02172	−0·03090	−0·76992	0·017550	1·06435	0·045441	1·95191	0·02630	1·38122
Total stock of dwellings	Not available	Not available			−0·000081	−1·09297	−0·000217	−2·20990	0·000173	1·51218
DEPENDENT VARIABLE= EXPENDITURE PER HEAD ON HOUSING										
Cost per foot super ...	0·29970	1·37811	−0·13908	−0·56260	−0·25879	−1·15104	−0·4797	−1·36231	−0·46194	−2·26003

* Each of these variables (except cost per foot super) replaced population and (population)^2, and a new set of equations was calculated. The coefficients of the other variables changed slightly, but these changes are not shown, to economise space.

Independent Variables	Dependent Variables								
	Cost of Ambulance Service per 1,000			% Administration Costs			Cost per Visit, Home Nursing Service		
	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2
COUNTY COUNCILS									
Constant α	392·63			29·442			−10·481		
Population	−0·0000248	−0·3158	0·0089	−0·0000112	−3·5822	0·1164	−0·00000248	−0·7935	0·0004
(Population)^2	0·00000199	0·6365	0·0117	0·00000033	2·6990	0·1357	0·00000011	0·8761	0·0208
Population Density	−38·4846	−0·9944	0·0286	1·1974	0·7209	0·0097			
Population/mile							−0·00505	−0·8922	0·0216
R.V. per capita	1·4124	0·6586	0·0126	−0·0056	−0·0689	0·0001	−0·0358	−0·4463	0·0044
Industrial R.V./Total R.V.	−89·0410	−0·4748	0·0065	8·2147	1·0998	0·0057			
Social Class	−0·6957	−0·0019	0·0000	12·7913	0·8530	0·0248	−10·6598	−0·7063	0·0135
Age	−3·4427	−0·5578	0·0090				−0·0461	−0·1724	0·0009
Average Earnings	−0·1634	−1·1324	0·0004	−0·0555	−1·1536	0·0136	0·0915	1·4490	0·0568
% Population in Urban Districts	1·6385	1·9060	0·1050	−0·1759	−0·477	0·0043	0·0739	0·6144	0·0101
	R^2=0·1619			R^2=0·4410			R^2=0·2699		
COUNTY BOROUGHS									
Constant α	1074·9			6·9236			2·5054		
Population	−0·000445	−3·0785	0·0200	−0·00000618	−1·0980	0·1062	−0·00000409	−1·3349	0·0115
(Population)^2	0·000420	2·7826	0·0912	−0·000000027	−0·0047	0·0000	0·00000249	0·7776	0·0080
Population Density				0·0881	1·1631	0·0162			
Population/mile	0·0451	0·6406	0·0048				0·00193	1·2116	0·0194
R.V. per capita	−0·6217	−0·5504	0·0036	0·07794	1·9145	0·0439	0·0587	2·2608	0·0674
Social Class	1·4535	0·5255	0·0033	−0·0027	−0·0262	0·0000	0·0453	0·7312	0·0070
Age	−1·8402	−0·5410	0·0035				−0·0498	−0·6766	0·0060
Average Earnings	−2·3961	−2·1555	0·0547	0·0150	0·3702	0·0016	0·00846	0·3507	0·0035
	R^2=0·1755			R^2=0·1498			R^2=0·1685		

HIGHWAYS ANALYSIS

Independent Variables	County Boroughs n=78: Expenditure per mile—unclassified roads			County Boroughs n=78: Total Expenditure per mile		
	β	t	ΔR^2	β	t	ΔR^2
Population	0·000150	0·3441	0·0031	0·000454	0·8632	0·0006
(Population)^2	−0·0000676	−0·1527	0·0003	−0·000456	−0·8518	0·0094
Population/mile	0·3319	1·5569	0·0292	0·4179	1·6206	0·0337
Rateable Value per capita	4·4107	1·2795	0·0197	4·4200	1·0602	0·0145
Average earnings	5·1062	0·6878	0·0264	2·1090	0·5049	0·0034
Social Class	1·3981	0·1883	0·0004	−2·2564	−0·2513	0·0016
Percentage Trunk Class I and II	−1·4717	0·1992	0·0005	1·7967	0·2011	0·0007
Flow per area	−0·4426	−0·9141	0·0010	−0·1445	−0·2468	0·0009
Heavy Vehicle Flow per area	0·9946	0·5318	0·0034	−0·3023	−0·1336	0·0004
Constant α	−1,190·4			−213·69		
	R^2=0·1807			R^2=0·1316		

Independent Variables	Non County Boroughs n=150: Expenditure per mile—unclassified roads			Non County Boroughs n=150: Total Expenditure per mile		
	β	t	ΔR^2	β	t	ΔR^2
Population	0·00119	0·2943	0·0316	−0·000188	−0·0500	0·0205
(Population)^2	−0·03816	−0·9312	0·0054	−0·01741	−0·4552	0·0013
Population/mile	0·6290	3·8720	0·0917	0·6142	4·0505	0·0989
Rateable Value per capita	1·6909	0·8636	0·0046	0·5250	0·2872	0·0005
Average earnings	0·2498	0·1369	0·0002	1·2000	0·7043	0·0030
Social Class	7·5737	1·7651	0·0191	6·1467	1·5346	0·0142
Percentage Trunk Class I and II	0·1568	0·0592	0·00002	−0·5896	−0·2383	0·0004
Flow per area	−0·1577	−0·3934	0·0009	−0·0275	−0·0735	0·0001
Heavy Vehicle Flow per area	0·7555	0·4338	0·0011	−0·3480	−0·2140	0·0003
Constant α	842·63			−207·39		
	R^2=0·1434			R^2=0·1561		

Independent Variables	Urban Districts n=69: Expenditure per mile—unclassified roads			Urban Districts n=69: Total Expenditure per mile		
	β	t	ΔR^2	β	t	ΔR^2
Population	−0·01299	−0·6223	0·0009	−0·00314	−1·0867	0·0420
(Population)^2	0·1134	0·7435	0·0068	0·03723	1·7644	0·0362
Population/mile	1·1965	3·6051	0·1587	0·09474	2·0636	0·0496
Rateable Value per capita	−11·0998	0·9726	0·0116	0·3612	0·2288	0·0006
Average earnings	−16·5619	1·1858	0·0172	0·6110	0·3163	0·0012
Social Class	46·7225	2·0169	0·00497	3·0855	0·9628	0·0108
Percentage Trunk Class I and II	−17·1753	1·0113	0·0126	−4·9772	−2·1185	0·0522
Flow per area	0·01767	0·2060	0·0006	−0·01709	−1·4400	0·0241
Heavy Vehicle Flow per area	−0·3321	−0·8475	0·0089	0·00204	0·3756	0·0017
Constant α	4,579·75			393·95		
	R^2=0·2800			R^2=0·3136		

COUNTY COUNCILS HIGHWAYS ANALYSIS n=38

Dependent Variable	Total Expenditure per mile			Trunk Road Expenditure per mile			Class I Road Expenditure per mile			Class II Road Expenditure per mile			Class III Road Expenditure per mile			Unclassified Road Expenditure per mile		
	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2	β	t	ΔR^2
Constant α=	−1,458·95			−6,557·4			1,841·22			−1,021·36			−1,395·05			−340·39		
Population	−0·000309	−1·3439	0·0004	−0·000671	0·4003	0·0011	−0·00140	−1·7255	0·0254	0·0001602	0·3793	0·0171	−0·0000736	−0·0357	0·0	−0·000182	−0·6974	0·0087
(Population)²	0·0000163	2·0170	0·0236	0·0000127	0·2146	0·0054	0·000110	3·8548	0·1194	0·0000243	1·6351	0·0138	0·0000149	2·0536	0·0218	0·0000038	0·4115	0·0042
Population/mile	1·4989	3·8561	0·0864	2·9650	1·0460	0·0260	1·4903	1·0873	0·0095	1·2550	1·7569	0·0160	0·9115	2·6146	0·0354	0·0564	1·2760	0·0364
Rateable Value per capita	5·3540	1·2235	0·0087	45·3890	1·4220	0·0491	27·2937	1·7686	0·0252	18·7605	2·3326	0·0282	3·8456	0·9800	0·0049	−2·0009	−0·4020	0·0040
Average Earnings	6·3100	1·9400	0·0230	27·7269	1·1987	0·0349	−5·1705	−0·4623	0·0017	3·1061	0·5329	0·0014	5·7138	2·0085	0·0209	2·1342	0·5917	0·0088
Flow of traffic/mile	−0·01377	−0·7537	0·0033	−0·1958	−1·4695	0·0524	0·06790	1·0541	0·0089	0·0193	0·5748	0·0017	−0·0025	−0·1531	0·0001	0·0054	0·2593	0·0016
		R^2=0·8199			R^2=0·2477			R^2=0·7509			R^2=0·8392			R^2=0·8395			R^2=0·2215	
Constant α=	−1,315·72			−6,703·14			1,735·07			−1,169·76			−1,345·36			−1,519·19		
Total Mileage	−0·05439	−0·7319	0·0040	−0·03089	−0·6002	0·0016	0·1641	0·5259	0·0002	0·1253	0·8764	0·0100	0·02812	0·3992	0·0010	−0·1013	−1·2844	0·0180
(Total Mileage)²	0·00000559	0·4941	0·0015	0·0000426	0·5442	0·0072	−2·8633	−0·6029	0·0046	−0·0000104	−0·4792	0·0014	−0·00000298	−0·2780	0·0006	0·0000126	1·0541	0·0268
Population/mile	1·5610	6·5790	0·2773	2·2013	1·3397	0·0433	3·2516	3·2648	0·1338	2·6842	5·8822	0·2076	1·4089	6·2654	0·2501	0·3642	1·4469	0·0504
Rateable Value per capita	2·5099	0·5816	0·0022	44·6559	1·4942	0·0539	43·2005	0·2385	0·0008	10·9230	1·3161	0·0108	0·1156	0·0283	0·0001	−2·0763	−0·4536	0·0050
Average Earnings	6·1103	1·8131	0·0210	29·6116	1·2687	0·0388	−4·9612	−0·3507	0·0015	3·2227	0·4972	0·0015	5·4910	1·7192	0·0188	1·9126	0·5350	0·0069
Flow of traffic/mile	−0·01398	−0·7362	0·0035	−0·2031	−1·5442	0·0576	0·07319	0·9180	0·0106	0·0251	0·6871	0·0030	−0·000415	−0·0231	0·0001	0·00415	0·0206	0·0012
		R^2=0·8014			R^2=0·2522			R^2=0·6109			R^2=0·8059			R^2=0·8025			R^2=0·2534	

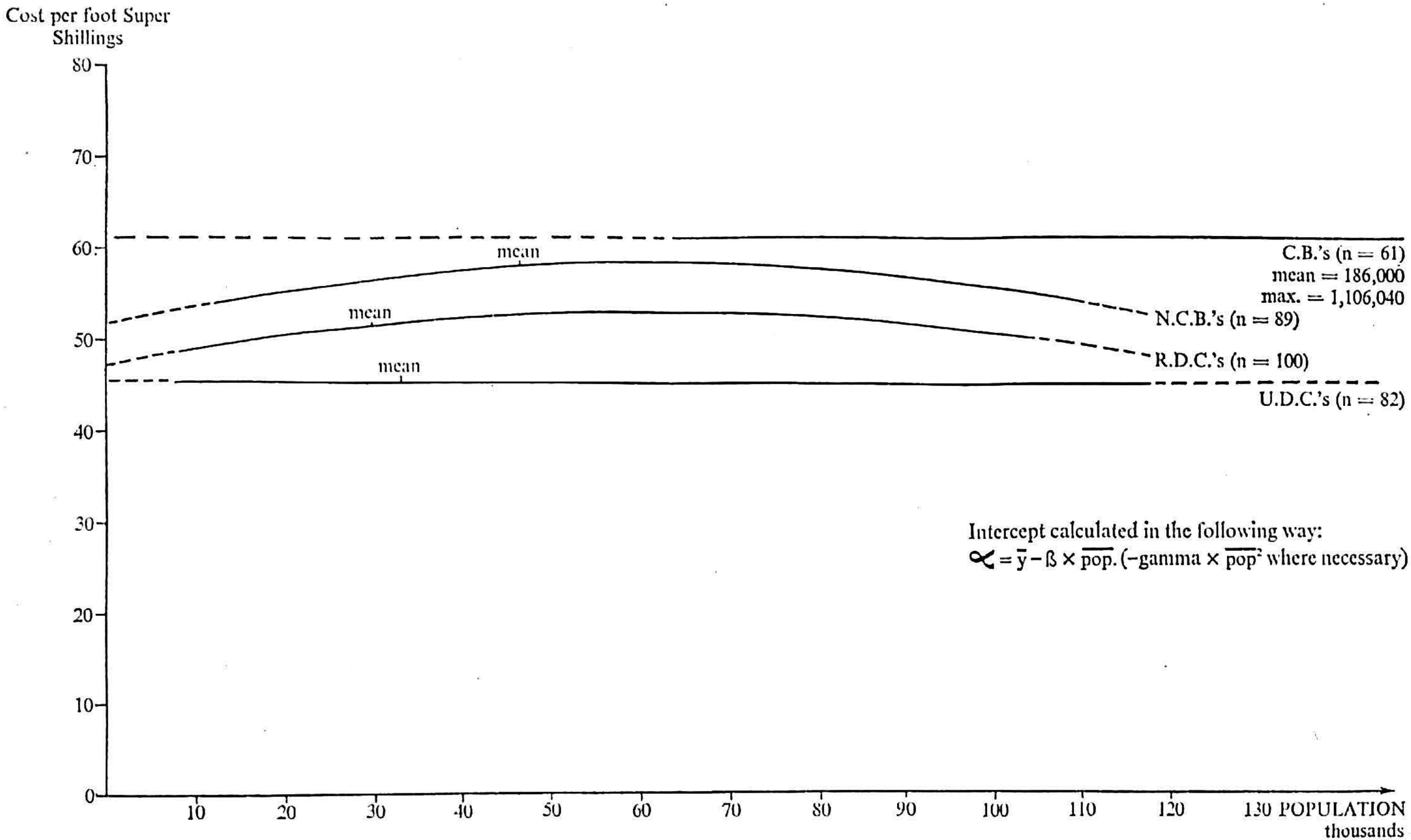
HIGHWAYS ANALYSIS

County Councils: Using Additional Variables (n=30)

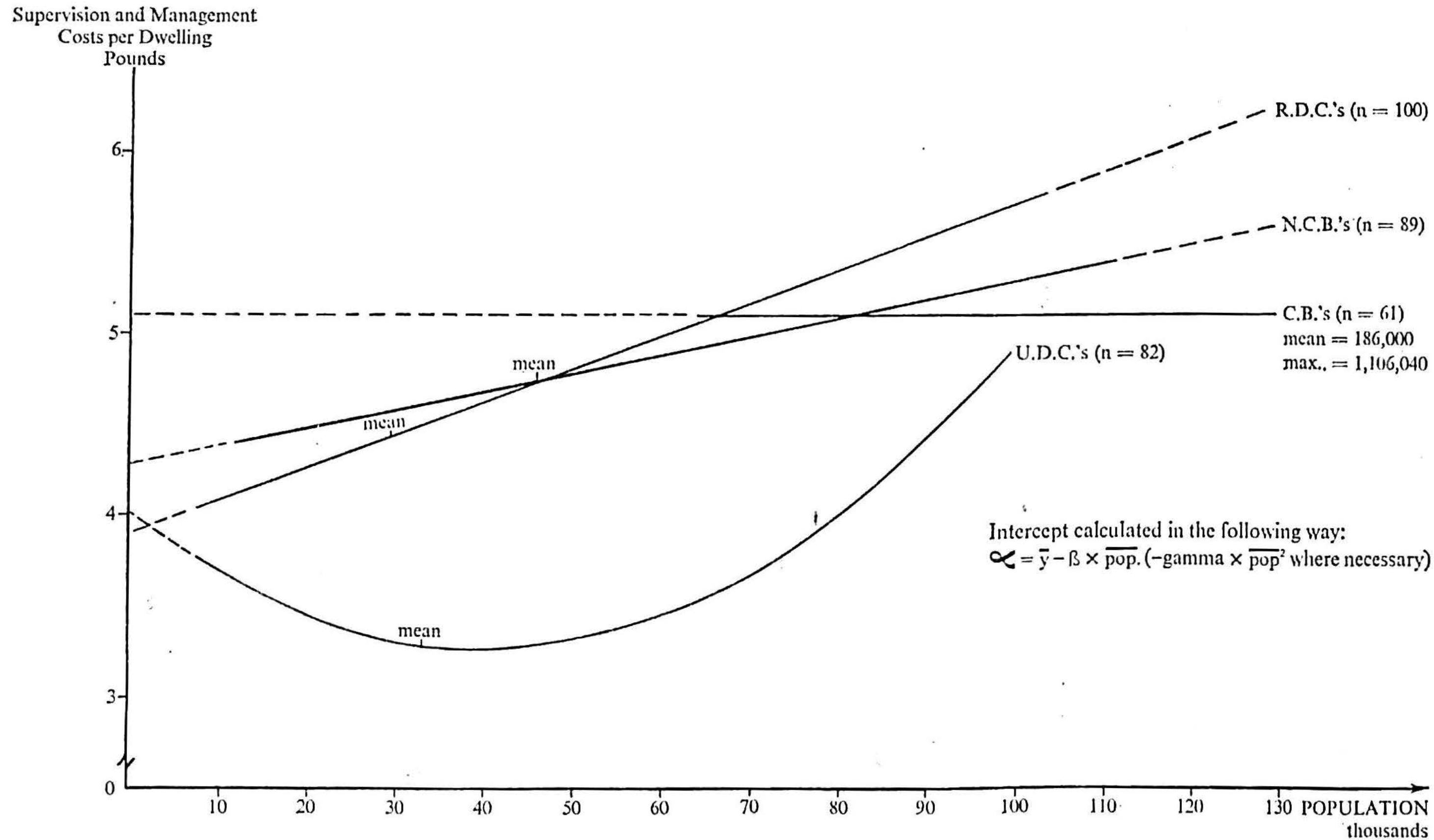
Independent Variables	β	t	β	t	β	t	β	t	β	t
Constant α=	−944·87		184·07		205·55		122·39		−25·647	
Population	−0·000367	−1·5329	−0·000404	−1·6732	−0·000376	−1·6131	−0·000477	−2·0023	−0·000369	−1·5254
(Population)^2	0·000014	1·4635	0·000015	1·6303	0·000014	1·5607	0·000017	1·7852	0·000014	1·5342
Population/mile	1·8405	3·4889	1·8848	3·4630	1·9282	3·6568	1·8114	3·3146	1·8416	3·4564
R.V. per capita	4·6873	2·5094	9·2574	1·6336	9·4424	1·7249	7·8652	1·3592	6·5333	1·1335
Flow per mile	−0·0147	−0·4174	−0·0137	−0·3798	−0·0170	−0·4894	−0·000921	−0·0259	−0·0163	−0·4564
K′/L′					−449·75	−1·6383				
K″/L″			−223·65	−1·0306						
% Hired Plant	946·88	1·2097					555·11	0·7184		
% Labour	926·28	1·6464							719·27	1·3287
	R^2=0·8402		R^2=0·8246		R^2=0·8356		R^2=0·8205		R^2=0·8295	

Note: The Dependent Variable for these equations was Total Expenditure per mile.

GRAPH 1. COST PER FOOT SUPER



GRAPH 2. SUPERVISION AND MANAGEMENT COSTS PER DWELLING



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The views expressed are, of course, the authors' responsibility.

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