ECONOMIES OF SCALE IN
BUS TRANSPORT

I. - Some British Municipal Results

By N. Lee and I. Steedman

This study was prompted by the proposal to merge a number of municipal transport undertakings into Passenger Transport Authorities. The initial White Paper, outlining these proposals, claimed that "The efficiency of bus operation is hampered by the small size of the undertakings" [1]. In a subsequent White Paper, this was qualified as follows: "Although there is no evidence that there is any particular optimum size of bus undertaking... there is a general consensus of view in the bus industry that the problems of effective management steadily increase as the number of buses in an undertaking rises above 1,000... On the other hand many of the existing municipal undertakings are clearly too small to be retained as individual units" [2].

It was decided, therefore, to subject the hypothesis of economies of scale to empirical test. This attempt inevitably developed into a broader investigation of variations in operating cost between bus undertakings.

The only previous empirical study of this sort in Britain was undertaken fifteen years ago and related to bus company operation [3]. It concluded that short-run average cost was a decreasing function of output over the whole of the observed output range, and that there was some indication (though not sufficient to justify a firm conclusion) that long-run average cost also declined with output.

This study, by contrast, relates to municipal bus operation, and is therefore limited to local authority undertakings predominantly engaged in the provision of stage carriage services in urban areas. These undertakings are all subject to a similar form of ownership and control and (particularly important) adopt a closely similar form of accounts, as recommended by the Institute of Municipal Treasurers and Accountants. At the same time, as in the case of other service industries, important elements of non-comparability remain. One of our major tasks has been to identify these and to separate their effect on the level of bus operating costs from the scale effect.

The basic data for this investigation was derived from the Annual Summary of Accounts and Statistical Information, 1967, published by the Municipal Passenger Transport Association. This was supplemented by the annual reports and accounts of the individual undertakings, and certain additional information was sought in a postal questionnaire.

Altogether there were 95 undertakings whose accounts and statistical information
were recorded in the 1967 M.P.T.A. publication, and these constitute the "population” in our investigation. Of this number 80 returned the questionnaire, partly or wholly completed; but some of these questionnaires had to be excluded because of incomplete answers or answers which failed to satisfy consistency checks, or because the undertakings provided significant non-bus vehicle mileage. Hence the number of undertakings included in the analysis was 44, or 46% of the total population. In Table 1 the characteristics of the sample are identified and compared with those of the population from which it is drawn.

**Table I — Characteristics of Sample**  
*(with selected population characteristics in brackets beneath)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Mean</th>
<th>Lowest Observation</th>
<th>Highest Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y_1 )</td>
<td>pence/bus mile</td>
<td>46.03</td>
<td>59.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(45.77)</td>
<td>(33.60)</td>
<td>(74.90)</td>
</tr>
<tr>
<td>( Y_2 )</td>
<td>&quot;</td>
<td>4.81</td>
<td>6.83</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.77)</td>
<td>(4.77)</td>
<td>(6.61)</td>
</tr>
<tr>
<td>( Y_3 )</td>
<td>&quot;</td>
<td>5.73</td>
<td>9.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.73)</td>
<td>(3.21)</td>
<td>(9.78)</td>
</tr>
<tr>
<td>( Y_4 )</td>
<td>&quot;</td>
<td>3.03</td>
<td>4.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.03)</td>
<td>(2.42)</td>
<td>(21.04)</td>
</tr>
<tr>
<td>( Y_5 )</td>
<td>&quot;</td>
<td>26.88</td>
<td>35.91</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(28.49)</td>
<td>(17.84)</td>
<td>(35.91)</td>
</tr>
<tr>
<td>( X_1 )</td>
<td>5 million miles</td>
<td>1.64</td>
<td>8.28</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.18)</td>
<td>(0.62)</td>
<td>(8.60)</td>
</tr>
<tr>
<td>( X_2 )</td>
<td>oo vehicles</td>
<td>2.74</td>
<td>16.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.98)</td>
<td>(0.07)</td>
<td>(16.69)</td>
</tr>
<tr>
<td>( X_3 )</td>
<td>ratio</td>
<td>0.98</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.98)</td>
<td>(0.82)</td>
<td>(1.04)</td>
</tr>
<tr>
<td>( X_4 )</td>
<td>pence/hour</td>
<td>104.2</td>
<td>110.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(104.6)</td>
<td>(100.8)</td>
<td>(110.8)</td>
</tr>
<tr>
<td>( X_5 )</td>
<td>&quot;</td>
<td>97.3</td>
<td>150.1</td>
<td></td>
</tr>
<tr>
<td>( X_6 )</td>
<td>pence/gallon</td>
<td>41.44</td>
<td>43.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(41.44)</td>
<td>(38.80)</td>
<td>(43.80)</td>
</tr>
<tr>
<td>( X_7 )</td>
<td>ratio</td>
<td>2.17</td>
<td>2.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.26)</td>
<td>(1.49)</td>
<td>(2.92)</td>
</tr>
<tr>
<td>( X_8 )</td>
<td>persons/acre</td>
<td>14.07</td>
<td>25.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(12.57)</td>
<td>(1.50)</td>
<td>(25.20)</td>
</tr>
<tr>
<td>( X_9 )</td>
<td>miles/hour</td>
<td>10.24</td>
<td>12.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10.24)</td>
<td>(8.60)</td>
<td>(12.30)</td>
</tr>
<tr>
<td>( X_{10} )</td>
<td>%</td>
<td>94.98</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(94.98)</td>
<td>(64.20)</td>
<td>(100.00)</td>
</tr>
<tr>
<td>( X_{11} )</td>
<td>000 miles/vehicle</td>
<td>31.47</td>
<td>40.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(29.41)</td>
<td>(24.49)</td>
<td>(40.31)</td>
</tr>
<tr>
<td>( X_{12} )</td>
<td>gallons/bus mile</td>
<td>0.11</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.12)</td>
<td>(0.08)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>( X_{13} )</td>
<td>hours/vehicle mile</td>
<td>0.318</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.318)</td>
<td>(0.25)</td>
<td>(0.39)</td>
</tr>
<tr>
<td>( X_{14} )</td>
<td>35 of the 44 undertakings included in the sample used the 1963 Recommended Form of Accounts.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The variables are defined on page 21.

*b*The second highest population observation was 59.90.

*c*The second highest population observation was 8.87.

*Only one population observation, Belfast, took this lowest value of 90.8, the lowest observation but one being 99.1.

*e*The lowest population observation but two was 18.54.
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In the following analysis the regression equations are estimated by single-equation ordinary least squares. The basic criterion adopted for reporting a regression equation is that it gives rise to the highest multiple correlation coefficient, corrected for degrees of freedom ($R^2$), subject to each independent variable in the regression being significant at least at the 10% level. The estimated coefficient of each independent variable has the modulus of its $t$ value printed in brackets immediately beneath it, and $R^2$ is given for each regression equation. In none of the reported regression equations was there any evidence of autocorrelation. We made no attempt to allow for the fact that some of the independent variables are certainly subject to error.

DEPENDENT VARIABLES

The main dependent variable selected is "Annual Total Working Expenses of Motor Buses" less "Alterations to Buildings and Other Items" per bus-mile, as defined in the I.M.T.A. 1963 Recommended Standard Form of Accounts.

Three points need to be made clear in this definition. First, the variable excludes expenses associated with trolley-bus and tram operation. The existence of these other transport activities within certain undertakings gives rise to the familiar problem of the arbitrary allocation to bus operation of a proportion of joint costs. To minimise the difficulty it was decided to exclude from the sample those undertakings which used trolley-buses and/or trams for more than 10% of their total annual vehicle mileage.

Secondly, "Alterations to Buildings and Other Items", though included within the standard definition of Total Working Expenses, can sometimes relate to elements of capital expenditure. In most cases this item is a relatively insignificant proportion of Total Working Expenses, but in certain undertakings, for the accounting year 1966–67, this was not so. The most satisfactory remedy appeared to be to exclude the item.

Thirdly, the standard definition of Total Working Expenses does not include provision for annual depreciation. Ideally, we should have wished to include this, but the difficulties arising from the use of different depreciation methods are particularly severe in municipal bus operation. After establishing that annual depreciation provision is not systematically related to any other component of total working expenses (particularly maintenance expenditure), we decided to omit the item, thus excluding bus capital costs from our analysis. In any case, the importance of annual depreciation provision relative to Total Working Expenses is quite small.

In addition it was decided to use the main components of Total Working Expenses of Motor Buses per bus mile as additional dependent variables in separate regressions. In fact, the procedure adopted was first to establish and test hypotheses relating to the component dependent variables and then to formulate and test hypotheses relating to the main dependent variable. The component dependent variables selected for analysis were:

- Power Costs per bus-mile;
- Traffic Operation Costs per bus-mile;
- Repair and Maintenance Costs per bus-mile;
- Management and General Expenses per bus-mile.
In each case the definition contained in the I.M.T.A. 1963 Recommended Standard Form of Accounts was adopted and the variables were calculated from annual data. It should be noted that Power Costs include certain fuel storage and associated labour costs and are, therefore, greater than annual expenditure on bus fuel.

INDEPENDENT VARIABLES

For ease of exposition the independent variables have been classified under five headings: size, factor prices, homogeneity of output, physical and traffic environment, and accounting. In other words, account was taken not only of size variations between undertakings but also of differences in the factor prices they pay, in the composition of the services they provide, in the environment in which they operate and in the manner in which they present their accounting data. As will be seen, it was not always possible to do this in a complete or entirely reliable manner.

Size Variables

Economies of scale imply that long-run average costs of production fall as the level of total output increases. There is some difficulty in defining a satisfactory measure of "output" for transport services, but two possible measures are annual bus mileage and annual bus passenger mileage. In practice, the former measure has to be used because of the absence of reliable data on the average length of passenger journeys. However, in the case of the component dependent variables it is arguable that there are other measures of size which may be more directly related to cost variation. Two such measures which are used in certain of the regressions are annual fuel consumption and average fleet size.1

One of the recognised difficulties in cross-sectional cost analysis is to identify the long-run relationship between cost and size from observations of undertakings of different scale which are not in long-term equilibrium. Recent shifts in demand, if unanticipated, will normally result in the observed (short-run) average cost being in excess of the corresponding long-run average cost for that scale of output. For this reason size change has been included as an independent variable, measuring the proportionate change in vehicle mileage relative to that in the previous year.

Factor Price Variables

In cross-sectional (as distinct from time series) analysis, variations in factor prices between observations frequently do not occur on a sufficient scale to merit attention. In this instance, however, because of differences in geographical location and because of the importance of labour in the provision of bus services, such variations cannot be ignored. A labour price variable has therefore been included, and two alternative specifications of this variable have been used in most of the regressions, since each specification is subject to certain (though different) limitations.

1Fleet size is defined as the arithmetic mean of the fleet sizes at the end of the financial years 1965–66 and 1966–67. It includes vehicles other than motor buses, but the correlation coefficient relating average fleet size and average motor bus fleet size is 0.9996.
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The first specification uses Ministry of Labour data on the average hourly earnings of men manual workers in manufacturing and certain other industries, for each Ministry of Labour region, in April 1966. This variable relates to a broader group of workers and to larger geographical areas than are ideal for this analysis. Almost certainly there are considerable variations in the price of labour within a region, and these may sometimes be greater than the variations between regions.

The alternative specification relates to average hourly earnings within the individual municipal transport undertakings in 1966-67. This data was derived from replies to the questionnaire, and in some instances was only an estimate. It is also important to recognise that this hourly rate is affected by factors additional to the state of the local labour market: for example, the extent of one-man operation. The implicit assumption in the use of this specification is that the average hourly rate paid by an undertaking is chiefly determined by the state of the local labour market.

There may also be regional variation in the price of fuel. Since fuel costs are a significant element in bus operating costs, it was decided to include fuel price as an explanatory variable where Power Costs/bus mile were taken as the dependent variable.

**Homogeneity of Output Variables**

It is impossible to take full account of the effect on operating costs of differences in the composition and quality of services. Therefore part of the unexplained variation in cost between undertakings must be due to unidentified differences in the services they provide. But four potential sources of non-comparability can be identified and taken into account by inclusion as independent variables in the appropriate regressions:

(a) *The percentage of bus-mileage on one-man operation.* This may reflect not only the quality of service but also the quality of management.

(b) *The time distribution of demand for bus services.* This is believed to be an important determinant of the average costs of bus operation. The usual hypothesis is that a more highly accentuated peak demand for bus services is associated with higher costs/bus-mile. In order to test this hypothesis it was necessary to assume that the incidence of the peak (measured by numbers of vehicles in use) was exogeneously determined, though, by such means as pricing and scheduling policies, some undertakings may in fact be influencing the incidence of their peak. Three peak variables were originally specified: (i) the daily work peak, (ii) the weekday/week-end peak, and (iii) the summer seasonal peak; but (iii) was not used because of the limited number of observations where the seasonal peak was recorded, and (ii) was not significant at the 10% level in any of the regressions.

*Peak measure (i):*

| Maximum number of buses in operation in peak period (Mon.–Fri.) |
| Average number of buses in operation in off-peak period (Mon.–Fri.) |

*Peak measure (ii):*

| Maximum number of buses in operation in peak period (Mon.–Fri.) |
| Average number of buses in operation on Sundays |
The third and fourth of our non-homogeneity variables do not appear in any of our finally selected regression equations. They are:

(c) The percentage of bus-mileage on double-deck operation. This varies widely between undertakings.

(d) The percentage of bus-mileage on stage service operation. Though stage service operation is the predominant activity of all municipal transport undertakings, its relative importance does vary from one undertaking to another, and it has different cost characteristics from other forms of operation.

Physical and Traffic Environment Variables

Variations between geographical areas in terrain and traffic conditions are a plausible explanatory factor in transport cost differences between undertakings. Terrain has to be largely ignored because of the difficulty of measuring its variation. Traffic also cannot be measured directly, but the residential density of population in the area may act as a proxy for it, on the hypothesis that density will be positively correlated with operating costs/bus-mile.

Alternatively, hilly terrain and congested traffic conditions should be reflected in slower average vehicle speeds, which are expected to be negatively correlated with operating costs/bus mile. Average bus speed might, therefore, be used as a proxy for terrain and traffic conditions, but there are difficulties. First, speed is affected by additional factors such as frequency of service stops and efficiency in scheduling. Secondly, undertakings do not calculate average bus speeds on a uniform basis. This data was collected from the replies to the questionnaire, and the main difference in definition observed was between scheduled speeds (as recorded in the time table) and actual speeds (taking into account running and lay-over time). An attempt was made to exclude observations for which the replies gave only a scheduled speed, but some inconsistencies remain and may have influenced the relationship established between speed and cost variation.

Other things being equal, variations in speed between undertakings will be reflected in variations in annual mileage/vehicle owned, a variable which can be more accurately measured than speed. Variations in the incidence of the peak will similarly lead to variations in vehicle utilisation. Therefore, although vehicle utilisation is not affected only by terrain and traffic conditions, it can be used as an explanatory variable in place of the speed and peak variables.

Accounting Variables

While the majority of the undertakings in the sample present their accounts according to the 1963 recommended standard form, a minority still employ the 1950 recommended standard form. No problem of comparability arises when using "Total Working Expenses" as the dependent variable, but differences do exist in the classification of its component elements. The significance of these differences is tested by the inclusion of a dummy variable in the appropriate regressions. As specified below, the coefficient of the dummy variable should be negative in all cases.

Scottish undertakings complete their financial year on 31 May; the financial year for other undertakings ends on 31 March. This could be a source of factor price non-comparability, but the number of Scottish undertakings in the sample is very small.
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NOTATION

In the reporting of the regression equations the following notation is used. Unless otherwise stated the variables are defined for the financial year 1966-67.

Dependent Variables

<table>
<thead>
<tr>
<th>$Y_1$</th>
<th>Total working expenses of motor buses less cost of alterations to buildings and other items, per bus-mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_2$</td>
<td>Power costs per bus-mile</td>
</tr>
<tr>
<td>$Y_3$</td>
<td>Repair and maintenance costs per bus-mile</td>
</tr>
<tr>
<td>$Y_4$</td>
<td>Management and general expenses per bus-mile</td>
</tr>
<tr>
<td>$Y_5$</td>
<td>Traffic operation costs per bus-mile</td>
</tr>
</tbody>
</table>

Units

- Pence per bus-mile

Independent Variables

<table>
<thead>
<tr>
<th>$X_1$</th>
<th>(Total) annual bus-mileage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_2$</td>
<td>(Average) fleet size</td>
</tr>
</tbody>
</table>
| $X_3$ | Size change = \[
\frac{\text{Total vehicle-mileage } 1966-67}{\text{Total vehicle-mileage } 1965-66}\]
| $X_4$ | Average hourly earnings of men manual workers in manufacturing and certain other industries, by region, in April 1966 |
| $X_5$ | Average hourly earnings in the individual municipal undertakings |
| $X_6$ | Average cost of fuel (after rebates) |
| $X_7$ | Incidence of the peak = \[
\frac{\text{Maximum number of buses in operation in the peak (Mon.-Fri.)}}{\text{Average number of buses in operation in the off-peak (Mon.-Fri.)}}\]
| $X_8$ | Residential population density in the area in which the individual municipal transport undertakings are located, as at April 1966 [4] |
| $X_9$ | Average speed of buses in operation |
| $X_{10}$ | Percentage of annual bus mileage on two-man operation |
| $X_{11}$ | Annual average mileage per vehicle |
| $X_{12}$ | Average fuel consumption by motor buses |
| $X_{13}$ | Average undertaking man-hours per vehicle-mile$^2$ |
| $X_{14}$ | Dummy variable: 1950 Accounts = 1, 1963 Accounts = 0 |

Units

- Five million miles
- Hundreds of vehicles
- Ratio
- Pence per hour
- Pence per gallon
- Ratio
- Persons per acre
- Miles per hour
- Percentage
- Thousands of miles per vehicle
- Gallons per bus-mile
- Hours per vehicle-mile

RESULTS OF THE REGRESSION ANALYSIS

The mean values of the dependent variables are:

- Power costs/bus mile ($Y_2$) 4.8d
- Repair and maintenance costs/bus mile ($Y_3$) 5.7d
- Management and general expenses/bus mile ($Y_4$) 3.0d
- Traffic operation costs/bus mile ($Y_5$) 28.9d
- Total working expenses/bus mile ($Y_1$) 46.0d

The components of Total Working Expenses not examined are Servicing Vehicles

$^2$Includes vehicles other than buses, and associated man-hours.
and Routes, Licences and Welfare and Medical Costs. Their combined mean value per bus-mile was 3.6d.

**Power Costs/Bus Mile (Y_2)**

\[
\log Y_2 = 0.513 + 0.790 \log X_6 + 0.862 \log X_{12} \quad (1)
\]

\[
(3.153) \quad (10.189) \quad (16.720)
\]

Of the observed variation in power costs per bus-mile, 73% can be explained by variations in fuel prices and vehicle fuel consumption; a 1% increase in fuel prices is associated with an increase in power costs/bus-mile of 0.79%, and an 1% increase in vehicle fuel consumption with one of 0.86%.

In fact, the observed variation in fuel prices was very small (all but four of the observations falling within the range 40-44d/gallon), and in explaining this variation only the percentage of bus-mileage on stage service operation was found to be significant at the 5% level, with negative sign. Since rebates are obtainable on fuel used in stage service operation, this was to be expected; but the \( \bar{R}^2 \) for this regression was only 0.129. Annual fuel consumption was not a significant variable in this regression, even at the 10% level; this indicates that large undertakings were not obtaining greater economies in fuel purchase than were the smaller undertakings. There is no indication that the smaller undertakings could only reap fuel economies at the expense of higher storage costs, since all size variables were non-significant at the 10% level in all the power cost regressions estimated.

Variations in fuel consumption/bus-mile were relatively greater than in fuel prices. In attempting to explain these variations, three variables were found significant at the 10% level: the residential density of the area in which the undertaking was located, the incidence of the work peak, and the proportion of bus mileage operated by double-deck buses (the last also being significant at the 5% level). While the three coefficients were all of the expected sign, the \( \bar{R}^2 \) for the regression of fuel consumption/bus mile on these three variables was only 0.280.

**Repair and Maintenance Costs/Bus Mile (Y_3)**

\[
Y_3 = 0.573 + 1.156 X_1 - 0.108 X_1^2 + 0.037 X_5 \quad (2)
\]

\[
(3.494) \quad (2.657) \quad (2.798) \quad (2.445)
\]

A notable feature of this equation is the quadratic scale effect; \( Y_3 \) attains a maximum value, for a given \( X_5 \), when \( X_1 = 5.351 \), i.e. when annual bus-mileage in nearly 27 million miles. In fact, only 4 undertakings in the sample exceeded this annual mileage. Given the same labour price (\( X_5 \)), undertakings achieving 27 million miles annually would be expected to incur repair and maintenance costs approximately 3d/bus mile higher than small undertakings achieving only about a million miles annually. It could be that the larger undertakings experience more difficult traffic conditions or have higher maintenance standards; but, as far as traffic conditions are concerned, the residential density variable was not significant at the 10% level in this regression equation. The variation in labour prices from 92d to 160d would account for a variation in \( Y_3 \) of 24d, whereas the actual variation in \( Y_3 \) is 6.6d, i.e. from 3.2d to 9.8d.

The best regression equation obtained when using the regional labour price variable was:

22
\[ Y_3 = -3.467 + 0.502 X_2 - 0.024 X_2^2 + 0.095 X_4 + 0.060 X_8 - 0.076 X_{11} \]  
\[ (2.542) \quad (1.863) \quad (1.849) \quad (1.527) \quad (1.571) \] 
\[ (R^2 = 0.407) \]

Again an “inverted” U-shaped cost curve is obtained, but in this case the size variable is the fleet size. \( Y_3 \) attains its maximum value, for given \( X_4, X_8 \) and \( X_{11} \), when \( X_2 = 10.458 \), that is, when the fleet size is slightly over 1,000 vehicles. Only in four undertakings in the sample is this fleet size exceeded.

**Management and General Expenses/Bus Mile \( (Y_4) \)**

\[ Y_4 = -0.367 + 0.053 X_4 - 0.067 X_{11} - 0.320 X_{14} \]  
\[ (2.237) \quad (3.102) \quad (1.588) \] 
\[ (R^2 = 0.291) \]

Little success was obtained in explaining the variation in \( Y_4 \). The regional labour price is superior to the undertaking labour price in explaining variations in management and general expenses. The sign of the accounting dummy variable \( (X_{14}) \) is as hypothesised, though it is not quite significant at the 10% level. The interpretation of \( X_{11} \) is not straightforward, since it is the product of a number of influences. The sign is plausible on the assumption that some components of management and general expenses were related to the number of buses (and/or the incidence of the peak) rather than to annual bus mileage. However, in all regressions of \( Y_4 \) which included annual bus-mileage \( (X_1) \) as an independent variable, the coefficient of \( X_1 \) was negative and insignificant at the 10% level.

**Traffic Operation Costs/Bus Mile \( (Y_5) \)**

\[ Y_5 = 14.546 + 0.102 X_3 + 0.191 X_4 + 0.100 X_{10} - 0.273 X_{11} - 2.578 X_{14} \]  
\[ (3.676) \quad (3.057) \quad (2.972) \quad (2.860) \quad (3.049) \] 
\[ (R^2 = 0.625) \]

\[ \log Y_5 = 0.573 + 0.323 \log X_3 + 0.160 \log X_4 + 0.082 \log X_8 - 0.297 \log X_9 \]  
\[ (2.987) \quad (2.913) \quad (2.056) \quad (2.341) \] 
\[ + 0.363 \log X_{10} - 0.100 X_{14} \]  
\[ (3.875) \quad (3.627) \] 
\[ (R^2 = 0.677) \]

\[ Y_5 = 4.073 + 0.247 X_4 + 0.247 X_8 + 0.081 X_10 - 0.372 X_{11} - 3.176 X_{14} \]  
\[ (2.243) \quad (3.710) \quad (2.136) \quad (3.800) \quad (3.501) \] 
\[ (R^2 = 0.551) \]

\[ \log Y_5 = -1.206 + 0.756 \log X_4 + 0.212 \log X_7 + 0.095 \log X_8 \]  
\[ (2.074) \quad (3.946) \quad (4.503) \] 
\[ - 0.342 \log X_9 + 0.322 \log X_{10} - 0.118 X_{14} \]  
\[ (2.594) \quad (3.140) \quad (4.155) \] 
\[ (R^2 = 0.641) \]

In view of the importance of traffic operation costs as a component of total working expenses, four equations have been reported—two include the undertaking labour price (linear and log. linear) and two use the regional labour price (linear and log. linear). It will be noted that better results are obtained with the undertaking labour price than with the regional labour price, and with a log. linear than with a linear expression.
In both the log linear regressions (6) and (8), traffic operation costs/bus mile are a positive function of the labour price \( (X_4 \text{ or } X_3) \), the incidence of the peak \( (X_7) \), residential population density \( (X_6) \) and the percentage of bus-mileage on two-man operation \( (X_{10}) \); but, as expected, they are a negative function of average bus speed \( (X_9) \) and the accounting dummy variable \( (X_{14}) \). In both regressions the elasticities are highest for the labour price, speed and two-man-operation variables. In the linear equations ((5) and (7)), the best results are obtained by substituting \( X_{11} \) (annual average miles/vehicle) for two of its determinants—\( X_7 \) (incidence of peak) and \( X_6 \) (bus speed). Otherwise the same independent variables are included as in the log linear regression equations.

In none of the above equations is size included as a significant variable. However, in certain equations with a lower \( R^2 \) the size effect was significant at the 10\% level. The “best” of these, including \( X_3 \) (undertaking labour price) and \( X_4 \) (regional labour price) respectively, were as follows:

\[
Y_3 = -3.323 - 0.267 X_2 + 0.128 X_6 + 2.345 X_7 + 0.241 X_3 \\
(1.971) \quad (4.354) \quad (2.742) \quad (3.129) \quad (9)
\]

\[
Y_3 = 1.180 + 0.380 X_1 + 0.220 X_4 + 1.913 X_7 - 0.973 X_9 \\
(1.699) \quad (1.804) \quad (2.006) \quad (2.038) \quad (10)
\]

\[
Y_3 = 0.112 X_{10} - 3.427 X_{14} \\
(2.571) \quad (3.423) \quad (11)
\]

Equation (9) is equivalent to equation (5) except that the size \( (X_2) \) and peak \( (X_7) \) variables have been substituted for the vehicle utilisation variable \( (X_{11}) \). Since \( R^2 \) falls only slightly and contains more fundamental explanatory variables, equation (9) may be regarded as the more informative. The size effect is significant at the 10\% level and its coefficient is negative, but its impact on traffic operating costs is relatively small. For given values of all the other variables the largest operator, with 1,650 vehicles, would be expected to incur traffic operating costs only 4d/bus-mile lower than the smallest operator, with only 50 vehicles. On the other hand, in equation (10) the scale effect is positive, which suggests that the direction of the size effect may not have been correctly identified. In equation (10) the regional labour price variable may have understated the labour price in the largest undertakings and thereby caused the change in sign of the size variable. Ultimately the interpretation placed upon the direction of the size effect on traffic operating costs depends upon whether the higher labour price paid by large undertakings is regarded as due to exogeneous factors in the local labour market or to diseconomies of scale within large undertakings.

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3 In view of earlier remarks a high correlation between residential density and vehicle speed might be expected, yet the correlation coefficient relating \( X_6 \) to \( X_9 \) was only 0.297, while that relating log \( X_9 \) to log \( X_6 \) was 0.179.

4 The change from \( X_3 \) to \( X_1 \) is unlikely to be the cause of the change in sign, since the correlation coefficient relating average fleet size to annual bus-mileage is 0.992.

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ECONOMIES OF SCALE IN BUS TRANSPORT: BRITAIN

N. Lee and I. Steedman

Total Working Expenses of Motor Buses/Bus-Mile \((Y_1)\)

\[
Y_1 = -22.336 + 0.237 X_3 + 132.783 X_{12} + 86.508 X_{13} \\
(7.853) \quad (2.808) \quad (7.054)
\]

\(\bar{R}^2 = 0.775\) \hspace{1cm} \hspace{1cm} (11)

\[
\log Y_1 = 2.208 - 0.875 \log X_3 + 0.361 \log X_5 + 0.047 \log X_4 + 0.301 \log X_{10} \\
(1.923) \quad (3.751) \quad (2.231) \quad (3.474) \\
- 0.236 \log X_{11} + 0.353 \log X_{12} \\
(2.343) \quad (2.402) \quad \bar{R}^2 = 0.676
\]

\[
\log Y_1 = 0.987 + 0.783 \log X_4 + 0.071 \log X_1 + 0.235 \log X_{10} \\
(2.139) \quad (3.120) \quad (2.321) \\
- 0.352 \log X_{11} + 0.384 \log X_{12} \\
(3.284) \quad (2.313) \quad \bar{R}^2 = 0.584
\]

Equation (11) identifies three variables which together explain nearly 80% of the variation in total working expenses/bus-mile. These are the undertaking labour price \((X_3)\), labour input/bus-mile \((X_{12})\), and fuel consumption \((X_{13})\). X_3 and X_{12} alone account for 75% of the variation in \(Y_1\), but \(X_{13}\) is really a compound effect of a group of more “fundamental” independent variables. Therefore, a series of regression equations were explored in sets of four (linear and log, linear using undertaking and regional labour prices, \(X_5\) and \(X_4\), alternately), substituting these more fundamental variables for \(X_{13}\), and of these regression equations the log, linear equations (12) and (13) have been selected for reporting. The equivalent linear equations have not been recorded, since they include the identical independent variables and have a slightly smaller \(\bar{R}^2\).

The scale effect is not significant at the 10% level in any of the regressions we have performed. This is not surprising, since the evidence of a scale effect on the component dependent variables was very slight—being significant at the 10% level only in the repair and maintenance costs equations. Furthermore, where \(X_3\) was used as the labour price variable, the diminishing returns in maintenance activity over the greater part of the observed range (equation (2)) may have been offset by increasing returns in traffic operation (equation (9)).

However, the size change variable is significant at the 10% level when combined with \(X_3\). The negative sign of \(\log X_3\) shows that, ceteris paribus, an undertaking whose vehicle mileage has dropped by (say) 20% relative to 1965–66 had higher total working expenses/bus-mile than an undertaking whose mileage had dropped by only 10%. This could be interpreted as showing that the former undertaking had adjusted less fully to its new scale of operation because of the greater extent of the adjustments necessary. On the other hand the negative sign also implies that, among undertakings whose mileage has increased, those with the greater increase will have the lower costs, which is apparently inconsistent with the above interpretation. In fact, only 11 undertakings within our sample recorded greater total mileages in 1966–67 than in 1965–66, and none of these increases was greater than 3% (whereas 33 undertakings recorded a decrease in annual mileage, in 11 cases by an amount greater than 3%). Given the small magnitude of the increase and the tendency of “public service” undertakings to maintain a margin of spare capacity, the negative sign of the coefficient is plausible within the limits of the observed values but could

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not be applied in a situation of substantial short-run increase in total mileage.\(^3\) This variable was also tested in the traffic operating cost \((T_3)\) regressions, where it was not significant at the 10% level, and this would suggest that cost elements not included in traffic operating costs are the slowest adjusters to size changes. At the same time it should be noted that the size change variable is not significant when combined with \(X_4\), the regional labour price variable.

The labour price variable is significant, with positive coefficient, at the 5% level—\ which is to be expected, since it has been found significant in all previous equations except the power costs regression \((1)\). Similarly, vehicle fuel consumption \((\log X_{12})\) is also significant at the 5% level with positive coefficient, which is plausible since it has been established as one of the prime determinants of variation in power costs. The inclusion of \(X_{10}\) (percentage two-man operation), significant at the 5% level with positive coefficient, was found significant in all the reported traffic operating cost regressions (equations \((5)-(10)\)); this emphasises the cost-reducing potential of one-man operation. But the coefficient of the variable requires careful interpretation, since it does not take into account either any increase in the undertaking labour price or any deterioration in quality of service which may arise from the extension of one-man operation.

The two other variables included in these regressions, \(\log X_6\) (residential density) and \(\log X_{11}\) (average mileage/vehicle), reflect differences between undertakings both in the composition of the services provided and in the physical and traffic conditions in which they operate. \(X_6\), significant at the 5% level with positive sign, has previously been reported as a significant explanatory variable in both the maintenance and the traffic operating cost regressions (equations \((3)\) and \((5)-(9)\)), whilst \(X_{11}\), significant at the 5% level with negative sign, has been reported in the management and general expenses and traffic operating cost regressions (equations \((4)\), \((5)-(7)\)). In an attempt to obtain a more fundamental explanation of the relationship between vehicle utilisation and total working expenses, \(\log X_7\) (peak variable) and \(\log X_9\) (speed variable) were substituted for \(\log X_{11}\). In equation \((14)\) \(R^2\), compared with equation \((12)\), declines slightly, and variables \(\log X_7\) and \(\log X_9\) cease to be significant at the 5% level \(\log X_9\) being previously excluded since it was not significant at the 10% level). In contrast, in equation \((15)\) \(R^2\) rises slightly, \(\log X_7\) being significant at the 5% level and \(\log X_9\) at the 10% level.

\[
\log T_1 = 2.088 - 0.974 \log X_3 + 0.381 \log X_5 + 0.097 \log X_7 + 0.037 \log X_9 \\
(2.086) \hspace{1cm} (3.825) \hspace{1cm} (1.634) \hspace{1cm} (1.771) \\
+ 0.305 \log X_{10} + 0.381 \log X_{12} \hspace{1cm} (14) \\
(3.401) \hspace{1cm} (2.457) \\
\text{\(R^2 = 0.653\)}
\]

\[
\log T_1 = 0.122 + 0.757 \log X_4 + 0.173 \log X_7 + 0.066 \log X_9 - 0.239 \log X_9 \\
(2.030) \hspace{1cm} (2.783) \hspace{1cm} (2.878) \hspace{1cm} (1.794) \\
+ 0.289 \log X_{10} + 0.397 \log X_{12} \hspace{1cm} (15) \\
(2.711) \hspace{1cm} (2.783) \\
\text{\(R^2 = 0.575\)}
\]

\(^3\)If the substantial increase occurred exclusively in the off-peak, working expenses/bus mile might continue to fall.
ECONOMIES OF SCALE IN BUS TRANSPORT: BRITAIN

CONCLUSIONS

The weight of our evidence supports the hypothesis of constant returns to scale in municipal bus operation. The tentative evidence of increasing returns to scale in traffic operation and, among the largest undertakings only, in maintenance and repair activity is not reflected in the variation in total working expenses. However, it is possible that scale economies might accrue to very large undertakings, such as the Passenger Transport Authorities, which are larger than any of the undertakings in our sample. Furthermore, it should be emphasised that, because of limitations of data, the scale hypothesis has been tested throughout with costs per bus-mile as the dependent variable. It is conceivable that a different scale effect might have been observed if costs per bus passenger-mile had been used as the dependent variable.

The variation in costs between undertakings of the same size is of far greater significance than the variation in costs between groups of undertakings of different size ranges. This variation is principally explained by differences in average hourly wage payments and in labour input per vehicle-mile. The difference in payment between undertakings is very considerable (ranging between 9d and 16d/hour) and, to some degree at least, is exogeneously determined through the regional labour market. Even within a regional area, however, there is considerable variation in the hourly wage payment made. If Passenger Transport Authorities were to standardise wage payments at the highest level paid by a constituent undertaking, without a compensating increase in labour productivity, then costs per bus-mile would be likely to increase by at least 4% for every 1% increase in average hourly payments. The wage standardisation effect on bus costs is potentially of far greater significance than the scale effect.

Labour input per vehicle-mile also varies considerably between undertakings (observations ranging between 0.25 man-hours and 0.39 man-hours). Since the majority of employees are engaged in traffic operating duties, this labour cost is principally influenced by the average speed of vehicles, the incidence of the peak (together with the associated method of rostering) and the extent of one-man operation. To a considerable degree these variables are exogeneously determined by the quality of service provided, the nature of employment in the area and traffic conditions. The reported equations indicate the adverse effect on costs of high residential densities, low average speeds, accentuated peak demands, and, in the short run anyway, of contractions in the scale of operation. It follows that social and economic changes affecting these variables will also affect the costs of municipal bus transport undertakings.

Our findings suggest that, within our range of observations, the main scope for cost reduction lies in the extension of one-man operation rather than in amalgamation; a 1% increase in one-man operation has been associated with a 1% decrease in traffic operating costs per bus-mile and a 4% decrease, approximately, in total working expenses per bus-mile. It must be remembered, however, that the extension of one-man operation may also lead to changes in the quality of service provided.

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6The elasticities mentioned here are taken from the regression equations using the *regional* labour price variable. Since the introduction of one-man operation must be expected to raise the *undertaking* labour price variable, use of the corresponding (higher) elasticities in the regression equations using the undertaking labour price variable would be misleading.
REFERENCES


University of Manchester