AN ANALYSIS OF TRENDS IN BUS PASSENGER MILES

By W. J. Tyson*

INTRODUCTION

The main purpose of this note is to describe a means of deriving passenger-mileage statistics for bus operation essentially from operators' fare scales. It also shows the application of the method described in an empirical study of changes in average journey length.

Passenger mileage is, of course, a much more meaningful measure of demand for transport than passenger journeys, as both the number of passengers and the length of journey influence the resource costs of meeting demand. But, with the exception of London Transport and at least one P.T.E., few operators measure passenger mileage, and little account of changes in journey length has been taken when preparing applications for fare increases, for example. Thus it would seem that changes in passenger numbers have been the basis of many policy decisions by the industry. It seems important, therefore, to compare trends in the two statistics in order to assess whether changes in passenger numbers are indicative of changes in passenger mileage and whether using the former as a proxy for the latter is justified.

THE METHOD OF ANALYSIS

Difficulties of measuring passenger mileage arise at least in part from the tariff structure commonly used in the bus industry. Fare and distance are not directly proportional to each other, as fare scales incorporate a taper: the longer the journey the lower the average fare per mile. In effect this comprises a two-part tariff, a fixed sum per trip (a charge for boarding) and a sum per mile travelled. As journey length increases the boarding charge is spread over more miles, and hence average fare per mile falls. It was, however, found by empirical observation that the fare scales of the operator studied in the next section (and subsequently those of many other operators) could be broken down into their fixed and variable elements by a simple regression equation, the form of which is:

\[ F = a + bD \]  

(a)

*University of Manchester. The author is indebted to the operator concerned and to its staff for making the data available and for consenting to the publication of the paper; and to Professor E. V. Morgan, Dr. N. Lee and Dr. P. C. Stubbs, of the University of Manchester, who commented on an earlier draft.
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where $F$ is the total fare paid (pence),
$D$ is the distance travelled at that fare (miles),
$a$ is the charge per trip (pence),
$b$ is the marginal rate per mile (pence).

The value of $r^2$ obtained from such regressions was very high, usually well in excess of 0.9, and it was thought that the estimates of the co-efficients $a$ and $b$ were sufficiently accurate to be used in the estimation of passenger mileage. This was done in the following manner. Total revenue can be represented in the form of an equation:

$$TR = aP + bM$$  \hspace{1cm} (b)

where $TR$ is total revenue (pence),
$P$ is the number of trips (that is, passenger numbers),
$M$ is passenger mileage.

By simple rearrangement of equation (b) it is possible to derive $M$:

$$bM = TR - aP$$  \hspace{1cm} (c)

$$M = \frac{(TR - aP)}{b}$$  \hspace{1cm} (d)

Thus $M$, passenger mileage, can be estimated from four statistics—total revenue, passenger numbers, and the parameters $a$ and $b$, which are themselves estimated from equation (a).

The first two statistics are readily available from most operators’ records, and data for estimation of the parameters ($a$ and $b$) are usually presented as part of the evidence submitted in support of an application to increase fares. The empirical study reported below therefore used this method and data supplied by the operator.

AN EMPIRICAL STUDY

General

In the study it was found that two further factors had to be taken into account. First, the above method could be applied only where all passengers had paid their fares on the same scale. In the case studied this condition was violated in two respects. Some routes were run by the operator jointly with other operators with different fare scales, and it was not possible to allocate passengers and revenue between them. This was avoided by eliminating jointly operated routes, leaving, however, about 93 per cent of passenger journeys in the analysis. The second problem was that of children travelling at half fares. It was impossible to estimate accurately their numbers and revenue in order that both could be eliminated from the analysis;

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1It can be seen from the $t$ value given in Table 1 that the co-efficients can be estimated with a high degree of accuracy. The range of error in journey length estimates was around six per cent on average, using the 95 per cent confidence limits of the estimated co-efficients.

2If this were not the case the relationship between $TR$, $M$ and $P$ would be different for each fare scale.
the estimates which follow will therefore be under-estimates of passenger mileages. Since the number of children travelling may have been falling more slowly than the number of passengers as a whole, the degree of under-estimation may have been rising over time.

The second factor which had to be taken into account was that passengers could travel a varying number of stages, and hence a variety of journey lengths, for any one fare; this affects the calculation of \( a \) and \( b \) from equation (a). It was assumed that on average passengers travelled the mean distance allowed for each fare. The time period for the study extended from the financial year ending 31 March 1961 to that ending 31 March 1969.

**Estimation of Parameters**

Statistics of the numbers of passengers and total revenue on all routes operated exclusively by the undertaking concerned were provided,\(^3\) together with the data necessary to calculate \( a \) and \( b \) for each of the fare scales in operation during this period.\(^4\)

The first stage was to carry out a regression analysis on each of the six fare scales in use during the period under study to obtain the co-efficients \( a \) and \( b \). The results are set out in Table 1.

**Table 1**

<table>
<thead>
<tr>
<th>Scale No.</th>
<th>Boarding Charge (d)</th>
<th>Fare Per Mile (d)</th>
<th>( r^2 )</th>
<th>( t )</th>
<th>Date Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.03</td>
<td>0.96</td>
<td>0.995</td>
<td>43.157</td>
<td>Pre-1960</td>
</tr>
<tr>
<td>2</td>
<td>2.24</td>
<td>1.07</td>
<td>0.982</td>
<td>22.120</td>
<td>Oct. 1961</td>
</tr>
<tr>
<td>3</td>
<td>2.85</td>
<td>1.08</td>
<td>0.972</td>
<td>15.562</td>
<td>Sep. 1962</td>
</tr>
<tr>
<td>4</td>
<td>2.76</td>
<td>1.32</td>
<td>0.885</td>
<td>18.860</td>
<td>Oct. 1963</td>
</tr>
<tr>
<td>5</td>
<td>2.82</td>
<td>1.56</td>
<td>0.990</td>
<td>22.132</td>
<td>July 1965</td>
</tr>
<tr>
<td>6</td>
<td>4.20</td>
<td>1.61</td>
<td>0.993</td>
<td>11.962</td>
<td>July 1967</td>
</tr>
</tbody>
</table>

Source: Calculations based on data provided by the operator.

Table 1 shows that with the exception of scales 4 and 5 there was a regular rise in the fare per trip, which increased by 106.9 per cent during the period. While the fare per mile rose steadily, the overall rise was only 67.19 per cent.

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\(^3\)Passenger journey statistics were derived from the number of tickets sold. For most of the period the principle was one ticket per passenger, but in the early years multiple ticket issue was practised. The method used did, however, allow the number of journeys to be obtained accurately from analysis of the number and denominations of tickets sold. Inaccuracy as a result of conductors' errors is inevitable, but is likely to be small in relation to the total. Revenue statistics were considered to be accurate, as they were derived from actual cash received.

\(^4\)These were tables giving the relationship between fare and distance and the period of operation of each fare scale.
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Results
From these data it was possible to calculate total passenger mileage in each year. In years in which a fare increase occurred separate figures were estimated for the periods before and after the increase. The results, together with passenger numbers for comparison and average journey lengths, are presented in Table 2.

Table 2

Estimates of Passenger Mileage and Numbers of Passengers

<table>
<thead>
<tr>
<th>Year Ending 31 March</th>
<th>Passenger Mileage (000)</th>
<th>Average Journey Length (miles)</th>
<th>Passengers (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960/61</td>
<td>1968/69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>664,500</td>
<td>2-20</td>
<td>301,336</td>
</tr>
<tr>
<td>1962</td>
<td>651,246</td>
<td>2-20</td>
<td>295,463</td>
</tr>
<tr>
<td>1963</td>
<td>642,523</td>
<td>2-28</td>
<td>281,871</td>
</tr>
<tr>
<td>1964</td>
<td>630,449</td>
<td>2-25</td>
<td>280,305</td>
</tr>
<tr>
<td>1965</td>
<td>604,560</td>
<td>2-26</td>
<td>264,913</td>
</tr>
<tr>
<td>1966</td>
<td>602,270</td>
<td>2-41</td>
<td>250,300</td>
</tr>
<tr>
<td>1967</td>
<td>610,876</td>
<td>2-55</td>
<td>239,380</td>
</tr>
<tr>
<td>1968</td>
<td>604,481</td>
<td>2-65</td>
<td>227,712</td>
</tr>
<tr>
<td>1969</td>
<td>614,729</td>
<td>2-93</td>
<td>209,641</td>
</tr>
</tbody>
</table>

Source: Data provided by the operator and calculations based on Table 1.

Even allowing for any errors implicit in the method of calculation, these figures show that there has been a significant difference in the rates at which the numbers of passengers and passenger mileage have been declining during the period. Passenger numbers have shown a fairly regular downward trend, with an overall loss of 30-43 per cent of the 1960/61 figure. Passenger mileage has shown a much lower rate of decrease, with some increase in recent years. Overall, the fall has been 7-49 per cent of the 1960/61 figure. (The lowest figure (that for 1965/66) showed a 9-36 per cent fall.) This is shown most clearly in the figures of average journey length, which, apart from 1963/64, have remained constant or risen over time, reflecting the fact that passenger mileage has not fallen as fast as passenger numbers.

The significance of this difference is reflected in the relationship between supply and demand. Over the period studied passengers per vehicle mile fell from 8-67 to 7-12, while passenger miles per vehicle mile rose from 19-13 to 20-86. Thus, any conclusions on the nature of changes in the relationship between demand and supply and any policy decisions arising from them depend on the statistics used.

There would seem to be several reasons for the change in average length of journey: two are worthy of discussion here. First, during this period considerable changes took place in the pattern of land use. Areas close to the city centre were cleared of high-density housing and their residents rehoused in lower-density estates.
away from the centre. While some trips (especially for shopping) were switched to other areas, a large proportion of work trips (in the first few years at least) continued to be made to the city centre, leading to some increase in average trip length by public transport.

The second reason is that the fares policy followed in this period resulted in higher increases for shorter distance fares than in those for longer journeys. The lowest fare increased by 200 per cent, the fare for a three-mile trip by only 140 per cent, and that for a five-mile journey by 70 per cent. In particular, the change from the fifth to the sixth scale (which occurred in 1967/68) involved a 100 per cent rise in the lowest fare and a 50 per cent rise in the next lowest, but only a 33, 25 or zero per cent rise in higher fares.

Table 2 shows, in fact, that the rate of increase in journey length rose considerably after 1964/65. Table 3 analyses changes in the fares for the shorter distances (0·5 mile and 1·0 mile), for which non-car-owners probably find walking is a ready substitute.

### Table 3

<table>
<thead>
<tr>
<th>Fare Increase</th>
<th>Rise in Fare for 0·5 mile</th>
<th>Rise in Fare for 1·0 mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 1961</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Sep. 1962</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Oct. 1963</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>July 1965</td>
<td>0%</td>
<td>33%</td>
</tr>
<tr>
<td>July 1967</td>
<td>100%</td>
<td>50%</td>
</tr>
</tbody>
</table>

During the period to 1965 journey length rose by only 3·64 per cent. Between then and 1966/67 (that is, during the currency of the July 1965 fare scale) it rose by 11·84 per cent, and between 1966/67 and 1968/69 (the currency of the July 1967 fare scale) it rose by 14·90 per cent. There would seem to be some a priori evidence of correlation between fare changes and increases in journey length.

Unfortunately, the period since the end of 1964/65 was also that in which population of the central area fell most rapidly (by 3·30 per cent before 1965 and by

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5Between 1961 and 1970 the population of the county borough in which the operator was based fell by 10·65 per cent, while that of the remainder of the area studied rose by 3·37 per cent. The percentage of total population living in the county borough fell from 68·30 to 65·07. Between 1968 and 1969 almost the entire fall of 9,020 in population in the whole area was accounted for by a drop of 9,015 persons living in the five electoral wards comprising the central core of the city. The rehousing was generally in peripheral overspill estates, where policy seemed to be to develop each in turn over about three years. As their distance from the central core varied, the change in journey length as a result of rehousing would also vary.

6An unpublished survey by the operator is the basis for this assertion.

7It should be noted that the relative increases in the boarding charge and rate per mile resulted from this policy rather than vice versa. It was the fares themselves which were the concern of policy when an increase was needed, not the boarding charge and rate per mile, which were the outcome of the fare values chosen for each distance.
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6.99 per cent between then and 1969). Thus, the effects of rehousing on journey length were also strongest then, and on the basis of available data there seems no way of testing for their separate effects. However, up to 1965 the percentage increase in journey length was about the same as the fall in central area population, whereas since then journey length has increased at over four times the rate at which population has fallen. This again points towards a correlation between fares policy and increasing journey length.

In the light of the results obtained it is also possible to discuss more meaningfully the significance of the problems caused by half fares and joint services mentioned above. It was argued that the degree of under-estimation of passenger mileage caused by children travelling at half fares might have increased during the period under study; therefore the fall in passenger mileage has probably been overstated and the increase in journey length understated. The jointly operated routes tended to be longer than the routes analysed, and were those on which there existed the greatest scope for increased journey length as a result of voluntary rehousing in peripheral areas. Both points seem, therefore, to lead to a degree of underestimation of the increase in journey length in the above figures. This should be borne in mind when reading the comparisons with other data discussed below.

COMPARISONS WITH OTHER DATA

There exist at least two other sets of data on passenger mileage for bus operators for the period examined—data for London Transport and for Great Britain as a whole. Both can be compared with the results of this study.

Great Britain as a Whole

The source of the national data is Passenger Transport in Great Britain, published annually by the Department of the Environment. Table 1 of that publication gives estimated passenger mileage by each mode for Great Britain, derived from operators' returns and the National Travel Survey. Table 5 gives passenger journeys, derived in the case of public service vehicles from operators' returns. If the period 1960 to 1969 is taken, figures for Great Britain as a whole (for all types of public service vehicle operation) show the following:

(a) Passenger mileage fell by 8.2 thousand millions from 43.9 thousand million to 35.7 thousand million—a fall of 18.68 per cent.

(b) Passenger numbers were reduced by 3,857 million, from 13,680 million to 9,823 million (28.19 per cent).

(c) Average journey length in consequence rose by 0.42 miles per passenger, from 3.21 miles to 3.63 miles (13.22 per cent).

These results can be compared with those derived from Table 2 above, which in summary are:

(a) A fall in passenger mileage of 7.49 per cent.

(b) A fall in passenger numbers of 30.43 per cent.

(c) A rise in average journey length of 33.18 per cent.

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The national data, however, are for all bus operations and are affected by a change in the share of different types in the total. In 1960, services other than stage-carriage services (that is, express, excursions and tours and contract services) accounted for 2.97 per cent of total passenger journeys; in 1969 this proportion had risen to 5.09 per cent. There is no direct evidence on the variation in length of journey amongst types of bus operation, but a priori it would be expected that journey length on non-stage services would be higher. So part of the national increase in journey length has come from the increase in the proportion of non-stage work in the total. But non-stage operations still account for a relatively small proportion of total passenger journeys, and stage-carriage work still forms the bulk of it.

When this is taken into consideration there is an even more marked contrast between the change in passenger mileage for the operator studied and that for stage-carriage operations in Great Britain as a whole. The fall in the area studied was less than average for the country as a whole, and this may mean that operators in at least some other areas have experienced a greater than average fall in passenger mileage. It is conceivable that in some areas journey length has been static or even decreasing.

London Transport

Comparison with figures for London Transport revealed a more startling contrast with this study. It would appear that the decline in passenger numbers in London was closely matched by a fall in passenger mileage over the 1961 to 1969 period. Hence average journey length rose only by 6.70 per cent, from 2.09 miles in 1961 to 2.23 miles in 1969.

Nothing is known about the detailed method by which the London (and the national) figures are compiled, and some of the differences may result from the methodologies used. A further reason in the case of London, however, is that the rail network carries a much higher proportion of peak-hour demand than the buses, which are used primarily for local journeys. Hence the effect on journey length of outward migration of population (whether voluntary or compulsory) is likely to be

9Passenger Transport in Great Britain 1970, op. cit. Tables 37, 39, 41 and 42 were used for data for these figures.
10In 1969 the share of vehicle mileage of non-stage services was 24.38 per cent, and they accounted for 18.28 per cent of receipts. As both vehicle mileage and receipts are likely in some way to be correlated with passenger mileage, this is some evidence in favour of the assertion. Furthermore, average receipts per passenger in 1969 were as follows: stage services (local authority) 3.0p, express services 26.5p, excursions and tours 37.6p and contract work 11.5p. This, too, in the absence of evidence of higher charges per mile in the non-stage sector, points towards longer journey length there.
11The source of the London Transport data is its Annual Reports. The figures refer to the existing London Transport area only (that is, the central bus area). Those for 1961 and 1962 were estimated from statistics for the central and country areas, whereas those for 1963 onwards are those provided in the 1971 Annual Report.
12See General Register Office, Sample Census 1966 Workplace and Transport Tables Part II (H.M.S.O., London, 1968). The 1966 sample census showed that 75.8 per cent of those working in the City of London travelled to work by train or tube. Comparable figures for Westminster and Camden were 55.4 and 48.2 per cent respectively.
felt on the trains rather than on the buses.\textsuperscript{13} (In the area studied in this analysis rail accounted for only 7.2 per cent of journeys to work in 1966.) Furthermore, there exist in London substantial areas relatively close to the centre which have not been extensively redeveloped on the same scale as the centre of the area analysed. Both these points would help to account for the observed difference between the London data and those of this study.

\textbf{SUMMARY AND CONCLUSIONS}

It has been demonstrated that it is possible to derive statistics of passenger miles for bus travellers relatively easily so long as the operator's fare scale can be broken into its constituent elements with some degree of accuracy.

The empirical application of the method in a large urban area for the 1960–1969 period showed a significant difference between trends in demand depending on whether passenger numbers or passenger miles was used as the measure. It would seem therefore that choice of the unit of demand is not only important for measurement itself (for example, in studies of price elasticity of demand) but for the policy decisions which follow changes in demand.

These results contrasted sharply with those for London Transport and Great Britain as a whole. A number of reasons could be postulated to explain the difference in the London figures. In view of the contrast with the national data, however, it would seem that some research into the relationships between passengers and passenger miles in other areas would be of interest.

\textsuperscript{13}There has been no significant increase in journey length on London Transport railways, however. This may again reflect the fact that they, too, cater primarily for shorter distance travel.