THE IMPACT OF REDUCED SERVICE QUALITY ON DEMAND FOR BUS TRAVEL

The Case of One-Man Operation

By Colin W. Boyd*

This paper describes the results of an analysis of the effects on passenger demand and operators' revenue of one-man operation of urban bus routes in Great Britain. Historically, both appropriate fare collection systems and the impact of one-man operation on operators' costs have been much studied by researchers. The results of their studies, however, do not provide a complete appraisal of one-man operation as an operational strategy adopted by the road passenger transport industry in the United Kingdom. That would require evidence of any change in demand and revenue produced by one-man operation. So far no generally applicable and relevant evidence has appeared, despite the widespread adoption of one-man operation over the past decade.

THE INTRODUCTION OF ONE-MAN OPERATION

In the 1960s the public road passenger transport industry in Great Britain entered a period of great uncertainty. With rising personal incomes and a rapid increase in car ownership, bus services were increasingly regarded as inferior goods. Demand for bus services, which had been relatively stable over the previous 30 years, declined dramatically. Simultaneously, high labour intensity made it difficult for bus operators to hold down costs, and hence prices, in a time of moderate wage inflation. The spiral of decline produced by escalating costs and diminishing revenue brought the industry to a point, in the late 1960s, where the financial viability of many operators became doubtful.

Two main responses to the changed circumstances of the industry can be identified:

1. External assistance in the form of grants and subsidies was much increased.1

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Table 1

<table>
<thead>
<tr>
<th>Financial year ending</th>
<th>Percentage of bus mileage one-man operated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>11.2</td>
</tr>
<tr>
<td>1969</td>
<td>16.1</td>
</tr>
<tr>
<td>1970</td>
<td>23.5</td>
</tr>
<tr>
<td>1971</td>
<td>31.6</td>
</tr>
<tr>
<td>1972</td>
<td>43.1</td>
</tr>
<tr>
<td>1973</td>
<td>53.1</td>
</tr>
<tr>
<td>1974</td>
<td>60.5</td>
</tr>
</tbody>
</table>


(2) Operators strove to increase labour productivity by the widespread introduction of one-man operation.

The National Board for Prices and Incomes played a critical role in advocating the introduction of one-man operation. Improvement of labour productivity by elimination of the need for the bus conductor was seen by the N.B.P.I. as a means of reducing operating costs, reducing the rate at which fares would rise, and easing problems of labour shortage and turnover. One-man operation had largely been confined to lightly used rural routes, but in the late 1960s it was extended to more heavily used, higher frequency urban routes. This was helped by the lifting of legal restrictions on the use of double-deck vehicles for one-man-operated services, and by capital grants to aid the purchase of vehicles fitted for one-man operation.

Table 1 indicates the extent and rate of adoption of the strategy by a sample of 31 municipal operators over the period 1968–74.

Of particular interest is the form in which the strategy was introduced in Great Britain. The practice with almost all one-man operated services was to retain fare collection by cash transactions on the vehicle, with some participation by the driver. In Continental Western Europe, by contrast, the introduction of one-man operation almost a decade earlier was generally accompanied by a trend towards the sale of most tickets in advance, off the vehicle. Experience in Great Britain was that on-board fare collection on one-man-operated buses increased passenger boarding time. Estimating the precise increase in marginal boarding time associated with

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2 The N.B.P.I. produced more reports on the bus industry than on any other individual industry, and placed great emphasis on one-man operation as a key strategy. See, for example, National Board for Prices and Incomes (1966), (1967), (1968).

3 See, for example, the survey published by Latscha (1967).
various fare collection systems was the topic of various studies, reviewed by Chapman (1975).

Increased time spent in boarding passengers at bus stops reduced productivity, offsetting some of the theoretical cost savings of one-man operation. Savings were further eroded by wage premiums and bonuses paid to driver-operators, and by expenditure on appropriate fare collection systems and vehicle configurations. Ex ante estimates of the possible cost savings from one-man operation ranged from 14% (Fishwick, 1970) to over 20% (Quarmby, 1974) of former operating costs. A saving of 15.6% was indicated by an ex post analysis conducted by Boyd (1981).

ONE-MAN OPERATION AND QUALITY OF SERVICE

It has been generally acknowledged that the increase in marginal boarding time associated with one-man operation of urban bus routes in Great Britain worsened the quality of service as perceived by passengers. A typical view was expressed by Kerridge (1974). He noted that the loss of the informal tasks performed by the conductor, the increase in in-vehicle journey time produced by increased marginal boarding time, and the general inconvenience of one-man operation would all tend to diminish the attractiveness of bus travel.

Several writers noted that increased marginal boarding time would further reduce service quality by increasing the propensity of buses on a route to pair together. This phenomenon, whereby schedule disturbances tend to intensify along the route and spread to successive vehicles because of uneven accumulation of passengers, was the subject of a pioneering paper by Newell and Potts (1964). Developing a simple model of these dynamics, they demonstrated that marginal boarding time was a critical factor in the instability of a bus schedule. The consequences for passengers of an increase in the systematic irregularity of service produced by introduction of one-man operation were noted by Jowett (1972). She mentioned that, aside from increased in-vehicle journey time, an increase in marginal boarding time would also increase average passenger waiting time, and make total travel time more variable.

There is little evidence that operators’ anticipation of reduced service quality deterred them from adopting one-man operation. This implies perhaps that demand was not generally expected to decline drastically. One exception was London Transport, which late in 1972 announced that it had decided to halt its programme of converting all its routes to one-man operation. Quarmby and Cohen (1973) summarised the reasons for this decision as follows: “In theory, one-man operation saves a good deal of cost compared to crew operation, and in the middle sixties was seen by the government as a very important way of increasing the productivity of the bus industry. But, in practice, the higher stop times due to pay-on-enter not only help erode the cost savings by requiring more buses and staff to maintain a given level of service, but they mark a deterioration of service to the passenger—leading to a loss of revenue.”

In the early 1970s some London Transport studies did attempt to predict the extent of revenue loss that would be produced by the introduction of one-man operation. These rough forecasts, based upon anticipated response of demand to change in
in-vehicle time only, were superseded by empirical evidence obtained from a 1972 study, reported by Fairhurst (1974). He found that conversion of London Transport suburban routes to 100% one-man operation had produced, on average, a 3% to 4% decrease in receipts. Fairhurst's study indicated losses in receipts approaching 8% for services with a typical urban headway of 10 minutes. To date this would appear to be the only reported investigation of the effect of one-man operation on revenue, though Cundill and Watts (1973) noted that estimates of revenue loss as high as 12% had been reported to the Transport and Road Research Laboratory.

The remainder of this paper describes the results of the author's investigations. These confirm that one-man operation has been associated with a decline in demand for bus travel and a reduction in operators' real revenue.

THE EFFECT OF ONE-MAN OPERATION ON DEMAND

The study presumed that demand for bus travel was determined according to the following model:

\[ P = a_0 e^{a_1 W} F^{a_2} M^{a_3} e^{a_4 t} \]  

(1)

where \( P \) is passengers carried per bus mile per year, \( W \) is the proportion of actual fleet mileage that is one-man operated per year, \( F \) is the average fare revenue per passenger per year expressed in January 1974 pounds by indexing in relation to the Retail Price Index, \( M \) is actual fleet mileage per year, \( t \) is a measure of time in years, and \( a_0, a_1, a_2, a_3 \) and \( a_4 \) are constants.

This model presumes that the conversion of an additional one percent of mileage to one-man operation will lead to the same percentage change in patronage, irrespective of the previous degree of one-man operation. Data were obtained for a sample of 31 municipal operators for the period 1968 to 1974 inclusive, the source being the Annual Summary of Accounts and Statistical Information published by the Municipal Passenger Transport Association up to 1969, and by the Association of Public Passenger Transport Operators from 1970 onwards. The names of the operators in the sample, together with statistics indicating the growth of their involvement in one-man operation over the period 1968 to 1974, are shown in Table 2.

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4 This model is derived from that used by Mullen (1975), whose general analytical approach was adopted for this study. In his reported analysis of demand elasticities Mullen attempted to model the effect of one-man operation but was frustrated by lack of adequate data. Initially this model contained an additional independent variable representing car ownership per capita within municipal boundaries. This variable was not found to be a significant determinant of demand for bus travel in any of the regressions, so it was eliminated from the model. Lack of data prevented the modelling of other possible variables, such as the growth in concessionary fares for the elderly.

Regression based on a logarithmic model applied to the absolute variables did not produce satisfactory results. This was because of severe multi-collinearity, as one-man operation was found to be strongly correlated with the time trend variable, reflecting the tendency for operators to increase their involvement with one-man operation over time. To eliminate the confounding influence of the time trend in the absolute levels of one-man operation, regression analysis was subsequently based on a first difference logarithmic transformation of the variables. This transformation enables the dependent demand variable to be directly specified, instead of being specified as demand per bus mile.
The following equation was produced, \( \Delta \) being the first difference operator (\( t \) values shown in parentheses):

\[
\Delta \log P = -0.007 - 0.048 \Delta W - 0.307 \Delta \log F + 0.613 \Delta \log M \\
(2.01) \quad (-1.65) \quad (-9.80) \quad (11.75)
\]

\[ R^2 = 0.62 \quad n = 186 \quad DW = 1.93 \]

The values of fare elasticity (-0.307) and mileage elasticity (+0.613) conform well to the generally acknowledged values produced by earlier research on demand elasticity. The slight time trend (-0.7% per annum) is of the expected sign.\(^6\) The coefficient for the one-man operation variable is of the expected sign, and indicates a patronage loss attributable to one-man operation of 4.7%. However, this result is not significant at the 5% confidence level.

Further analysis of the data indicated a significant correlation between annual change in fares and annual change in the degree of one-man operation. It was also found that there was a significant correlation between annual change in the level of demand and the previous year’s change in the degree of one-man operation. These features are shown in Table 3, which gives the matrix of simple correlation coefficients between the variables representing concurrent changes in demand, fares, mileage and one-man operation and the variables representing the immediately preceding year’s changes in fares, mileage and one-man operation.

The significant positive correlation between concurrent change in fares and one-man operation (echoed by the slightly higher correlation between \( \Delta W_{-1} \) and \( \Delta \log F_{-1} \)) is an unusual finding. It suggests the absence of the anticipated reductions in real fares that would have arisen if operators had passed on to passengers some of the cost savings produced by one-man operation. There are however several

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\(^6\) This figure is less than, for example, the annual percentage change in demand of -4.3% over the period 1962-72 quoted by Webster (1975). Webster’s figure, of course, represents aggregate decline, whereas the figure of 0.7% per annum represents the remaining decline after disaggregation and separation of the effects of the modelled service parameters.
possible factors which, individually or in combination, could militate against reduction of fares and could account for the positive association between change in revenue per passenger and change in the degree of one-man operation in the same time period:

(1) The financial position of many operators may have been so difficult that those which had to introduce the greatest levels of one-man operation were those which simultaneously were forced to introduce the highest fare increases.

(2) Operators may have revised fare structures when introducing one-man operation. It was generally recognised that many of the operational problems of one-man operation were diminished by the simplification of fare structures, but that this simplification may have resulted in revenue loss. Operators may have anticipated this by increasing average fares when they revised fare structures.

(3) Operators may have reacted to or anticipated patronage loss attributable to one-man operation itself, and introduced higher fares to maintain revenue.

(4) Revised fare structures and/or the effect of one-man operation itself may have deterred short-distance travellers. With a graduated fare structure any reduction in the proportion of short-distance travellers, who pay less than average fares, will result in an apparent increase in average revenue per passenger. If one-man operation is associated with this change in travel patterns, the strategy will appear to be associated with higher average fares.

If any of these factors resulted in the positive association of higher fare increases with higher incremental changes in the level of one-man operation, then clearly it is difficult to identify conclusively the effect of one-man operation on demand. That one-man operation itself does have an adverse effect on demand is indicated by the revelation in Table 3 of a significant lagged relationship between one-man operation and demand. The correlation matrix does not indicate that demand is affected by the preceding year’s change in actual mileage operated or (more important) by the preceding year’s fare changes.

The literature on empirical analysis of the elasticities of demand for bus travel does not appear to embrace any study of lagged demand response. The discovery of an apparent lagged response to one-man operation in this study was accidental and not therefore the result of prior hypothesis. Accordingly the study was not explicitly designed to identify any precise demand decay function, and the nature of the data used forces us to the interpretation that any significant lagged response takes place over a two-year time period. If monthly data had been available, for example, it would have been possible to identify more precisely the response of demand over time to changes in fares, mileage and the extent of one-man operation.

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7 See, for example, various papers presented at the Symposium on Public Transport Fare Structure (Transport and Road Research Laboratory. 1974).

8 The author’s analysis of cost savings produced by one-man operation revealed the existence of time lags in the full realisation of cost savings, reflecting the delay in the shedding or absorption of the excess labour produced. The lagged data sets produced for the cost analysis were accidentally found to indicate the lagged response of demand.
The confirmation of the apparent existence of a lagged response to one-man operation is shown in equation 3 of the table of regression results presented in Table 4. In this equation the variables representing the lagged effects of fares and mileage upon demand are not significant. Variable $\Delta W_{-1}$ is significant, and indicates a patronage loss of 6.7% attributable to one-man operation in the year after introduction or extension of one-man-operated services. This estimate is virtually unaffected by the elimination in equation 4 of variables $\Delta \log F_{-1}$ and $\Delta \log M_{-1}$. In equation 5, however, when $\Delta \log F$ is eliminated, variable $\Delta W$ becomes significant as well, reflecting the effect of positive correlation between concurrent changes in real fares and levels of one-man operation as revealed in the correlation matrix. Equation 5 indicates that one-man operation reduces patronage by 10.6% in the year of introduction, and by a further 6.7% in the following year. This estimate of 10.6% for the first year's patronage loss is unreliable, however, coming from an equation in which an important explanatory variable is missing.

Equation 6 in Table 4 eliminates the apparently insignificant first-year one-man-operation variable $\Delta W$. The second year effect is still significant, indicating a 7.4% patronage loss, with a 95% confidence interval of 2.6% to 12.0% for this estimate. Finally, in equation 7 the one-man-operation variables are replaced by an individual variable $(\Delta W + \Delta W_{-1})$ representing the increase in one-man operation over a two-year period. This variable, again significant, indicates a total patronage loss of 10.8% attributable to one-man operation over a two-year period. The 95% confidence interval for this estimate is 4.5% to 16.7%.

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9 It should be noted that any estimate of the coefficient of variable $(\Delta W + \Delta W_{-1})$ must be doubled to obtain an estimate of the effect of one-man operation on demand, because of double counting.

10 For the sake of brevity the results of the analysis of revenue effects of one-man operation are not presented. These results are nearly identical to the demand effect in the results presented.
CONCLUSIONS

The results obtained from this study indicate that one-man operation reduced patronage and revenue for a group of 31 municipal operators by around 11%, with a lower bound of around 7%. However, for two reasons these results cannot be regarded as fully conclusive. Firstly, the relationship between fares and one-man operation confounds the full revelation of the effect of one-man operation on demand and revenue, and most probably results in the under-identification of the first-year effect. Secondly, although the analysis indicates a significant lagged effect of one-man operation on demand, no prior hypothesis was proposed to justify the potential existence and particular structure of a lagged response.

There is an ex-post explanation of the existence of a lagged response to one-man operation, and the absence of a lagged response to changes in fares and mileage operated. Passengers’ behaviour over time in response to the stimulus of a change in bus travel service may be presumed to be as follows:

1. Perception of change:
   - time taken to recognise the changed service characteristics;
   - time taken to recognise the permanency of the change.

2. Response to perceived change:
   - time taken to evaluate change in number of journeys taken or means of travel;
   - time taken to implement changed use of transport.

Clearly, the time taken to perceive the effects and permanency of changes in service may differ according to the nature of the service characteristic. Table 5 presents various hypothetical passenger perceptions to changes in a range of service characteristics. It seems highly likely that passenger response to the novel and complex effects of one-man operation, which may initially be regarded as teething problems, will take longer than response to fare increases or increased headways, the effects of which are well known, simple and probably perceived as permanent. The possible existence of delayed demand response to changes in the more complex aspects of bus travel service quality would appear to be a fruitful topic for future investigation.

Overall, one-man operation cannot be adjudged to have been a completely successful strategy for the U.K. road passenger transport industry. At a time of declining demand for its services, the industry responded with a strategy that offered an inferior good to that which was offered before, without any apparent reduction in price. This would appear to have exacerbated, rather than stemmed, the decline in demand that was a primary cause of the difficulties of the industry in the mid 1960s.

From the perspective of transport policy, judgement on the success of one-man operation cannot be favourable. Grant aid has supported a strategy that seems to have diverted passengers away from one of the more economic modes of urban transport. One-man operation almost certainly has resulted in a net welfare cost: the benefits appear small by comparison with the increased generalised cost of travel for remaining passengers, the cost of diversion of passengers to other modes, and the congestion costs imposed by buses halting longer at bus stops.
**Table 5**

Hypothetical Passenger Perceptions of Change in Various Bus Travel Service Characteristics

<table>
<thead>
<tr>
<th>Bus Travel Service Characteristics</th>
<th>Fare Level</th>
<th>Headway (Scheduled Mileage)</th>
<th>Ad hoc Service Cancellation (Actual Mileage)</th>
<th>Road Congestion</th>
<th>Conversion to One-Man Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of change in characteristic</td>
<td>Increased price</td>
<td>Increased waiting time</td>
<td>Random increases in waiting time</td>
<td>Random increases in journey time</td>
<td>Reduced intangible service quality, random increases in waiting time, journey time, and travel time variability</td>
</tr>
<tr>
<td>Has changed characteristic been experienced by passengers before?</td>
<td>Yes</td>
<td>Probably</td>
<td>Probably</td>
<td>Probably</td>
<td>No</td>
</tr>
<tr>
<td>Time for effect of change to be perceived</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Immediate, though there may be a considerable delay before a pattern of service deterioration becomes established, and before this pattern is subsequently recognised by passengers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will change be recognised as permanent?</td>
<td>Yes</td>
<td>Yes</td>
<td>Not necessarily, for passengers may be optimistic that service deterioration may be corrected (e.g. by increased recruitment, provision of bus lanes, and improvement in boarding procedures, respectively)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable time-lag before demand responds to changed characteristic</td>
<td>Short-term</td>
<td>Short-term</td>
<td>Medium to long-term</td>
<td>Medium to long-term</td>
<td>Medium to long-term</td>
</tr>
</tbody>
</table>
REFERENCES


