COMPETITION ON AN URBAN BUS ROUTE

By Stephen Glaister*

In any debate on the likely outcome of removing quantity regulation from the stage carriage bus industry, one of the central issues is how far the services offered will adjust to meet demands that are latent under the present system, and which of the services now offered might disappear. The work reported in this paper was a first attempt to investigate this question in the context of a particular route.

One view of urban bus services is that they have developed in an orderly fashion under the influence of even-handed regulation and effective management, and that the levels of service and fares are the best that can reasonably be expected. At best, the industry is stagnant. At worst, decline is inevitable unless increasing levels of subsidy are provided. An alternative view is that the system of regulation, and latterly of increasing subsidy, has encouraged the ossification of the industry by protecting it from the need to adapt itself to economic and social changes. As a result it is declining more rapidly and consumes more financial support than it needs to do. Authors such as Walters (1982), Hibbs (1983) and Roth and Wynne (1982) catalogue towns overseas where traditional regulation has ceased for one reason or another and competitive, and in many cases reasonably high quality, services have emerged and found it possible to survive comfortably on a commercial basis (Hong Kong, Kuala Lumpur, Buenos Aires, Calcutta, Manila, Istanbul, Cairo, Singapore, Nairobi, Belfast).

These places differ in important respects from the United Kingdom, so it is an open question whether there is a fundamental obstacle to similar developments here. It is apparent that the answer depends crucially on (a) what happens to costs and (b) how far new demand can be generated.

New demand can only be created if fares fall, if there is an improvement in one or more of the many aspects of service quality, or if some new kinds of service are offered. New kinds of service can come about if the relaxation of regulation encourages greater flexibility and differentiated products more closely suited to the varying individual needs of consumers. Among other things this would lead one to expect more variation than at present in the kinds and sizes of vehicles.

Overseas experience seems to support this expectation. Walters (1982) has

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* London School of Economics. This is the paper referred to in paragraph 23 of Annex 2 to the White Paper, Buses, (Cmdn. 9300). In preparing it I benefited greatly from comments and criticisms from Michael Beesley, Malcolm Buchanan and officials of the Department of Transport. I am solely responsible for the content.
suggested that the use of smaller vehicles can also improve service quality. He argues that, though several small buses will have higher total labour and capital costs than the equivalent large vehicle, they will provide a higher frequency of service. Given quite modest assumptions about the value attached to the saving of waiting time, passengers would be more than willing to pay the extra fare required to cover the higher costs: the vehicle which minimises the sum of operating costs and passenger time costs is likely to be smaller than the traditional vehicle.

There are several subsidiary arguments.

(i) The small vehicle has to pick up and set down less frequently. It will therefore achieve a higher speed, which in turn improves its output of seat miles and benefits passengers by reducing their time in the vehicle.

(ii) Several small vehicles can serve a wider range of destinations than one large vehicle, and because each carries fewer people it can more easily adopt ad hoc route variations to suit individual passengers.

(iii) These improvements for the passenger will generate new demand for bus travel, especially from those who value the improvements highly and those who will make their trip on foot unless a bus happens to come along at the right moment.

(iv) This will itself generate extra revenue for the industry, and especially for the small vehicle, leading to a further expansion of the level of service offered.

A proliferation of small vehicles may have some other effects which would generally be judged to be undesirable.

(i) There is the possibility that they would cause a net increase in traffic flows and thus make congestion worse.

(ii) One of the essential features of the big vehicle carrying a relatively large number of passengers is that the labour costs can be spread more thinly which implies lower money fares. There may be a section of the population that does not greatly value the improvement in service that the smaller vehicle can provide. If competition leads to a significant reduction in the number of the cheaper, large vehicles that are on offer, that group may be disadvantaged.

These are the issues considered in this paper. Because of the inherent intractability of a mathematical approach it seemed that the most productive avenue would be by stochastic simulation: that is, by using a computer to trace through events as they might actually occur on a representation of a real bus route.

**THE CHANGES INVESTIGATED**

The White Paper, *Buses* (Department of Transport, 1984), sets out the Government's intentions on future levels of support for the industry. These were taken as assumptions for the present work. It is helpful to keep in mind a distinction between the effects of three types of changes. They are:

(i) the effect of reducing subsidy to one third of its present level while maintaining the system of regulation intact;
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(ii) the effect of achieving a reduction in costs of the magnitude indicated in the White Paper;
(iii) the additional effect of removing the restrictions imposed by quantity licensing.

It was a premise in the present work that the reduction in subsidy will be achieved, so the discussion of the effects of cost reduction and deregulation is generally relative to a low subsidy “bench mark”.

One other important distinction is that between a prediction of what will happen under certain circumstances and an evaluation to decide whether an outcome is better or worse than another from the point of view of particular groups. Prediction is the primary concern of this paper. The groups whose interests one might wish to consider in an evaluation include the existing operators and their employees; operators and employees who might enter the industry; consumers, present and potential, categorised by trip purpose, socioeconomic characteristics, degree of urbanisation, present level of service, etc.; non-users such as users of private cars and taxis; and local and central authorities.

THE ROUTE

It was desirable that the route modelled should represent known conditions “on the ground” so far as possible, so we initially used information to hand from an earlier study (Beesley, Gist and Glaister, 1983, p. 210) which refers to a corridor of 4.4 miles from Fleet Street to Bishops Bridge Road, London. It was served by several bus routes. In the peak there were about 76 buses per hour and 4,400 passengers per hour past a point. Off peak there were 39 buses per hour and 900 passengers per hour (3 hours peak, 15 hours off peak, 5 days per week). It was thought that the model would display rather better some of the difficulties faced by provincial bus operators if it were modelled to have the “geography” shown in Figures 1 to 12. The central section of 5 miles is fed by six links, each of two miles. The central stop spacing approximates to that found in central London, but, since the corridor is served by several routes, a “stop” marked on the diagram represents several actual bus boarding and alighting points.

THE PASSENGERS

Three cases were treated: high flow, medium flow, and low flow. High flow was intended to represent a morning peak with a dominant heavy flow from the “suburbs” into the centre of town. The low flow case exhibited an even pattern of demand such as might occur during the between-peak period. In the high flow case the rates of passenger demand were taken to approximate the peak flow, except that, instead of spreading the demand evenly across the route, we transferred 80 per cent from the last four central stops to the first four (that is, stops 2 to 5). This was intended to represent a typical pattern of concentrated demand for travel into the centre, with relatively thin demand on the outbound
leg. The demand at each of six remote inbound termini was taken to be 176 passengers per hour, so that the six together roundly make up the average demand to be found at one of the other stops. For the medium flow case all the demands were divided by two, and then they were distributed in the ratio of 90:10 as against 80:20 for the high flow case. The low flow case was derived from the high flow by dividing all the flows by five (in line with the off-peak figures for the London example) and distributing the demand evenly across the route.

Passengers were assumed to have an elasticity with respect to price of -0.2 in the high and medium flow cases and -0.4 in the low flow case. These values are, perhaps, a little on the low side, but the evidence is good that they are of this general order of magnitude for urban bus operations. They mean that bus passengers are fairly insensitive in their behaviour to changes in fares.

For any individual the value of a time saving varies considerably, according to the urgency of the trip involved and the unpleasantness of spending time on it (for example, waiting at a bus stop). It also varies between individuals because of (among other things) variations in income. The Department of Transport supplied a distribution of values of time for bus users. This was derived from the distribution of household incomes of the population of bus users observed in the National Travel Survey, by assuming that time values are proportional to income. For simplicity the distribution of time values was divided into three equal parts with in-vehicle time values of £0.34, £0.81 and £1.44 per hour. Thus the arrivals of passengers at each stop were assumed to be from three sub-populations, initially of equal size. Service quality was calculated separately at each stop in terms of the time expected to be spent in waiting to board a bus (valued at twice in-vehicle time) and time spent in the vehicle. Putting this together with the assumed response to changes in money fares yielded an implied response to changes in quality of service. In this way the demand from each of the three groups of passengers at each of the stops was determined by the fares being charged and the quality of service being offered.

All passengers were assumed to have an average trip length of 1.4 miles while travelling on the central section of the route. A passenger of one of the six limbs was bound to travel at least the full two miles to or from the central section. (The average for the whole of London is about 2.2 miles. In fact there is reason to expect that those with higher time values would have longer trip lengths; this would favour the smaller and faster vehicle.) The actual distance that an individual passenger chose to travel was determined by a random process, so that the total number of passengers wishing to alight from a particular vehicle at a stop was binomially distributed.

THE VEHICLE, COSTS AND FARES

When moving, buses of all sizes were assumed to achieve 8 miles per hour. A large bus had a capacity of 88 seats and a small one a capacity of 15. There is some support from overseas experience for the use of a 15 seat minibus. Some work done by the Transport and Road Research Laboratory indicates that this is at the low end of the range of vehicle sizes that would be optimal under a variety
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of assumptions. It is quite possible that 25 or 35 would turn out to be a more appropriate size in many circumstances.

Estimates of costs for big and small buses in present and competitive conditions were provided by the Department of Transport. Expressed as money costs per hour they took the form:

\[
\text{(wage/utilisation + capital costs and one half maintenance) + (one half maintenance + fuel and tyres) x speed}
\]

They were (in £ per hour, speeds in mph):

**Big bus:**
- Non-competitive: \((5.2/0.7 + 4.3) + (0.275 + 0.15) \times \text{speed}\)
- Competitive: \((3.7/0.8 + 2.7) + (0.115 + 0.15) \times \text{speed}\).

**Small Bus:**
- Non-competitive: \((5.2 \times 0.9/0.7 + 1.95) + (0.10 + 0.08) \times \text{speed}\)
- Competitive: \((3.2/0.8 + 1.4) + (0.06 + 0.08) \times \text{speed}\).

These costs were multiplied by 2/3 or 8/9 or unity, according to whether subsidy was to be paid at a rate of 1/3 of costs or at 1/3 of that rate (that is, 1/9 of costs) or not paid at all.

Bus operators were assumed to fix a fare per passenger mile which would just cover their costs, given their overall achieved speeds, on the assumption that a “target” load was achieved. The London example shows that the average load for a big bus is 58 in the peak and 23 off peak. But this is in a situation of a fairly even spread of passenger traffic. A more realistic expectation in the very uneven conditions assumed for the high and medium flows is a target load of 40 for a big bus and 7 for a small bus (29 and 5 for low flows). For the small bus these are conservative assumptions: overseas experience is that small vehicles typically achieve higher load factors.

THE COMPETITIVE MARKET

The rules for competitive entry to and exit from operation on the route were as follows. If loads were found to exceed the target load over a period of time, profits would be made and a new vehicle would enter the trade. Conversely, if loads were too low over a period, losses would be made and one of the vehicles currently making a loss would be eliminated.

This yielded an equilibrium with the predetermined target load factors. An important equilibrating mechanism was the variation of achieved speeds — and therefore of revenue-earning capacity — as average time spent at stops by each vehicle varied; this in turn depended on the numbers boarding and alighting. In practice there would be a further adjustment as the willingness of the demand side of the market as a whole to pay for reduced waiting and in-vehicle time was weighed against what could be offered by the supply side of the market if fares were to be raised whilst load factors were lowered. This important adjustment was not followed through. However, as will become apparent, individuals with
different time values tend to sort themselves on to vehicles with appropriate speeds, and this mitigates the problems posed by the restriction to average cost pricing at fixed target load factors.

The arrivals of passengers at stops were assumed to be according to random (Poisson) processes. There was a different arrival rate for each stop and for each of the three passenger types. The arrival rate of each type of passenger at each stop was determined by the total of the money cost and the value of time expended in making a trip. The times expended comprised time queueing while waiting for the next suitable non-full bus, and the time spent in the vehicle. The latter depended upon the speed achieved, which, in turn, depended upon vehicle size. When a bus was at a stop the passenger at the head of the queue had to decide whether or not to board it. The probability that he would do so was determined by the various components of the cost of using that vehicle, relative to those of the alternatives: the money fares, the value of in-vehicle time (and hence speeds and values of time), and expected waiting time for the arrival of the next vehicle. If only big buses were running he would certainly take the first available bus.

The choice probability was a logistic having the form \(1/[1+ \exp(-10z)]\), where \(z\) is the difference in the generalised costs (in £) by the two modes for the individual concerned. The coefficient of 10 on the \(z\) determines the propensity to discriminate against a vehicle which is slower or more expensive. If costs and times were equal, the chances of choosing a bus of a particular kind would be 50:50; but if one bus were 10 pence per passenger mile more expensive than the other, the chances of choosing it would fall to about 25:75, unless there was a compensating change in service quality. A ten-pence-worth change in relative time costs would have the same effect. This parameter therefore determined the extent to which the two kinds of vehicles discriminated between passengers with high and low values of time, but some limited experiments indicated that it was not central to the conclusion that a mix of vehicles would emerge in many circumstances. If the parameter were assumed to be zero, each vehicle would carry equal proportions of the passenger types.

A bus approaching a stop had to stop if it had a passenger wishing to alight. It remained at the stop to pick up passengers (or stopped to do so if not already stopped) if it had spare capacity and if the buses already at the stop were not more than seven and their available seating capacity was less than the queue length. A bus would move off when it was full or when the queue was empty.

Each passenger boarding or alighting delayed the bus for one standard time unit (2.5 seconds; in practice smaller vehicles might experience somewhat longer boarding times). In addition vehicles incurred deceleration and acceleration delay if they had to stop. The vehicles were assigned to each of the six routes in strict rotation as they arrived at the branch point. No vehicles were allowed to "turn short". Revenues were imputed to a bus from all its passengers each time it stopped, in an amount proportional to the distance from the last stop. There were six census points. When a bus passed one of these its passengers were counted and various other statistics were updated. At intervals a complete review of the situation was undertaken, and buses were taken out of service or brought into service, according to profit or loss.

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RESULTS

Results\(^1\) are presented in Figures 1 to 12 for four sets of circumstances for the high flow case (Figures 1 to 4), four for the medium flow case (Figures 5 to 8), and four for the low flow case (Figures 9 to 12). The circumstances are:

(i) The present level of costs, the present level of subsidy (that is, 1/3 of costs) and only large buses operating.
(ii) As (i) except that subsidy is reduced by a factor of three to 1/9 of costs.
(iii) As (ii) but with entry of small vehicles allowed in competition with the big buses.
(iv) Costs brought down to fully competitive levels and subsidy eliminated, with free competition between vehicle types.

The twelve “maps” summarise the results. At each “stop” (representing in reality a bunch of bus stopping places) \(Q\) represents a typical queue length and \(W\) represents the total time in minutes that a passenger would expect to have to wait to move down the queue and then find a bus with space. That time is determined both by the length of the queue and by the speed at which the queue is moving. Note that the quoted bus flow rates include vehicles which are full at some points on the route.

High flows

In Figure 1 there are 88 big buses. Much congestion of passengers is apparent towards the beginning of the central part of the route, as many of the buses become full. Service at the termini is good, with waiting times of about four and a half minutes. The fare is 3.7 pence per passenger mile. A typical load contains roughly equal proportions of the three groups of passengers.

Figure 2 shows the effect of reducing subsidy levels. The bus fare increases to 4.9 pence per passenger mile, and the number of buses falls to 67. Waiting times are only slightly worse, but the passenger market has contracted by about 24 per cent.

In Figure 3 small buses are allowed to enter the market competitively; it is assumed that both types of vehicles have 1/9 of their costs covered by subsidy. Sixteen of the big buses are replaced by 157 small buses, which travel at 7.7 mph as against 6.6 mph. The small buses charge a fare three times as high as the big buses. Overall service levels improve very substantially. The service frequency of the big bus at low fares is reduced, but there are still big buses available for those who want them. The overall passenger market is expanded to something approaching the initial level (that of Figure 1), but the proportion of travellers with high time values is higher, small vehicles having twice as many passengers with high time values as with low values.

\(^1\) There is a problem in presenting the results of this simulation exercise. Arrivals of passengers and their trip lengths were assumed to follow random processes. It is characteristic of these that they have high variances. As a result there is continuous variation as time passes in such things as queue lengths and bus loads. Hence the results presented represent the situation at one particular instant, and there is a degree of arbitrariness in the choice.
Number of big buses = 88; speed = 6.6 mph
Big bus fare = 3.7 pence/pm
Filled seat miles = 23,232/hour

Typical big bus load
Low  Medium  High
14.4  14.6  14.0

**FIGURE 1**

*High flows; non-competitive costs; 1/3 subsidy; big bus only*

Number of big buses = 67; speed = 6.59 mph
Big bus fare = 4.9 pence/pm
Filled seat miles = 17,661/hour

Typical big bus load
Low  Medium  High
19.9  19.6  18.9

**FIGURE 2**

*High flows; non-competitive costs; 1/9 subsidy; big bus only*
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Number of big buses = 51; speed = 6.62 mph
Number of small buses = 157; speed = 7.69 mph
Big bus fare = 4.9 pence/pm
Small bus fare = 16.6 pence/pm
Filled seat miles = 21,956/hour

Low  Medium  High
Typical big bus load  11.8  14.8  14.6
Typical small bus load  1.6  2.3  3.2

FIGURE 3

High flows; non-competitive costs; 1/9 subsidy; big and small buses

Number of big buses = 40; speed = 6.60 mph
Number of small buses = 222; speed = 7.67 mph
Big bus fare = 3.4 pence/pm
Small bus fare = 12.1 pence/pm
Filled seat miles = 22,479/hour

Low  Medium  High
Typical big bus load  12.3  13.4  12.9
Typical small bus load  2.0  2.6  3.6

FIGURE 4

High flows; competitive costs; zero subsidy; big and small buses

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Number of big buses = 54; speed = 6.74 mph
Big bus fare = 3.6 pence/pm
Filled seat miles = 14,407/hour

Typical big bus load  | Low | Medium | High
14.1 | 15.5 | 13.9

FIGURE 5

Medium flows; non-competitive costs; 1/3 subsidy; big bus only

Number of big buses = 30; speed = 6.88 mph
Big bus fare = 4.7 pence/pm
Filled seat miles = 8,256/hour

Typical big bus load  | Low | Medium | High
14.2 | 10.4 | 7.5

FIGURE 6

Medium flows; non-competitive costs; 1/9 subsidy; big bus only
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Number of big buses = 11; speed = 6.88 mph
Number of small buses = 114; speed = 7.74 mph
Big bus fare = 4.7 pence/pm
Small bus fare = 16.5 pence/pm
Filled seat miles = 9,204/hour

Typical big bus load
15.8
16.4
17.4

Typical small bus load
1.7
2.2
2.6

FIGURE 7

Medium flows; non-competitive costs; 1/9 subsidy; big and small buses

Number of big buses = 17; speed = 6.72 mph
Number of small buses = 122; speed = 7.71 mph
Big bus fare = 3.4 pence/pm
Small bus fare = 12.0 pence/pm
Filled seat miles = 11,154/hour

Typical big bus load
10.7
8.6
10.4

Typical small bus load
2.2
3.0
3.5

FIGURE 8

Medium flows; competitive costs; zero subsidy; big and small buses
FIGURE 9

Low flows; non-competitive costs; 1/3 subsidy; big bus only

Number of big buses = 24; speed = 6.97 mph
Big bus fare = 4.5 pence/pm
Filled seat miles = 4,851/hour

Typical big bus load

Low Medium High
8.7 9.0 8.5

FIGURE 10

Low flows; non-competitive costs; 1/9 subsidy; big bus only

Number of big buses = 22; speed = 7.04 mph
Big bus fares = 6.0 pence/pm
Filled seat miles = 4,491/hour

Typical big bus load

Low Medium High
8.3 10.3 10.6
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Number of big buses = 0
Number of small buses = 108; speed = 7.78 mph
Big bus fare = n/a
Small bus fare = 23 pence/pm
Filled seat miles = 4,201/hour

Typical small bus load
Low  Medium  High
1.0    1.4    3.5

FIGURE 11

Low flows; non-competitive costs; 1/9 subsidy; big and small buses

Number of big buses = 0
Number of small buses = 165; speed = 7.73 mph
Big bus fare = n/a
Small bus fare = 17.6 pence/pm
Filled seat miles = 6,377/hour

Typical small bus loads
Low  Medium  High
0.6   1.4    4.0

FIGURE 12

Low flows; competitive costs; zero subsidy; big and small buses
When we move to Figure 4, costs are reduced to competitive levels but subsidies are removed. Fares are reduced, for the big bus to 3.4 pence per passenger mile. This is slightly less than the initial fare in Figure 1. There are 11 fewer big buses than in Figure 3 (leaving 40) and 65 more small buses (making 222). Service levels are much improved over those of Figure 3 at the remote termini, where the buses are rarely full, but they are somewhat worse at some points in the centre of town because of the tendency of the small buses to fill up. This illustrates the distinctive advantages of vehicle sizes: the small vehicle is able to offer better service frequencies in the relatively “thin” parts of the routes, and the big vehicle can provide the capacity to cope with the areas of heavy demand. The total passenger market expands further and is now close to the initial level.

Between the beginning (Figure 1) and the last stage (Figure 4), subsidy has been eliminated and costs have enjoyed an offsetting fall. Big bus fares have been reduced slightly, and in most cases service levels have improved. The big bus survives to provide a service for those not wishing to pay for the improved services, arriving every 2.3 minutes on average as against the original 1 minute.

**Low flow results**

In the low flow cases the big bus is not able to offer a very good service, especially if the subsidy is reduced. If competition is allowed the big bus disappears completely (Figures 11 and 12). Services are much better with small buses than with big, even if subsidies are removed without costs being reduced (compare Figures 9 and 11); but, since the cheap big bus is now no longer available, fares faced by all passengers are much higher than they were initially. This would particularly disadvantage the traveller with a low time value, who would not gain so much from the improvements in service. The detailed results (not shown here) confirm that this group is made worse off because the total of its fare and time costs has risen. But the rise is quite small (from 17 to 19 pence per passenger mile), and it is clear that the magnitude of the gains to those who do gain outweight the losses of those who lose. Of course one cannot conclude that this will always be true.

Note that it is assumed throughout that small buses would achieve low average loads – only five in the low flow case. If they managed to do better than this, their fares would be lower: a doubling of loads would cause a halving of fares. One other qualification concerns the allocation of costs. We have assumed that the capital costs are allocated evenly throughout the day. But if the high (or medium) flow case is taken to represent a peak and the low flow an off peak, a conclusion that big buses would only run in the peak seems implausible. It is more likely that competition would enforce a form of cost “allocation”, with a corresponding fares structure, which would result in at least some vehicles of each kind operating at both times of day.

The medium flow results do not add greatly to those that have already been discussed.

The development of bunching of vehicles was observed from time to time and this could affect the economics of the industry for substantial periods. Bunching appeared to be less severe when there was a large number of small vehicles than when there were fewer large vehicles.
Traffic congestion

Tables 1 and 2 summarise a crude assessment of the implications for traffic flows and speeds of the various cases for high flows and medium flows. The speed/flow relationships used are those used in the Department of Transport's model for the assessment of public transport subsidy. Other assumptions are noted in the tables. The speed changes shown are significant. Note that they assume speed/flow slopes thought to be typical of London conditions, and the effects might be about half as great in a typical metropolitan area. Of course, what would happen in practice would depend upon how far the improved service quality offered by the smaller vehicle, especially to those with high time values, succeeded in seducing the users of private cars and taxis on to buses. It would also depend on the size of any small vehicles that appeared: if they were 30-seaters rather than the 15-seaters assumed, there would be fewer of them and their congesting effects would be less severe.

CONCLUSION

The aim of this exercise was to investigate the validity of some of the claims that have been made for the possible effects of deregulation in an urban area. We have found no reason to doubt that overseas experience would, in general, be repeated under a deregulated regime in the United Kingdom. Small vehicles would play an important part. Fares on small vehicles might well be higher than on larger ones. In high flow areas, big buses would remain available at low fares (but with reduced frequencies), with smaller vehicles offering much improved frequencies and faster journeys, but at higher fares. Smaller vehicles would thus tend to carry a relatively higher proportion of people with high time values. In low flow areas, those with low time values might be made worse off, since the number of cheap big buses might be very substantially reduced. So for many people, the service frequencies would be better, and interchange easier. But for poorer people, the effect might in some circumstances be the opposite. It is possible that the gains would outweigh the losses, even if the subsidy given to the industry were substantially reduced or eliminated.

Reducing subsidy from 1/3 of costs to 1/9 of costs, with no other changes in the system of regulation or in costs, would have a severe effect on fares, service levels, demand and output. Better planning of services, within the present institutional framework, would mitigate this in some degree. Cost reduction of the magnitude hypothesised in the White Paper may well only be possible if stimulated by deregulation: the amount taken off subsidy would then be similar to the amount taken off costs.

Other things being equal, the following would tend to favour the small vehicle rather than the big: low flows, wide variety of destinations, wide variance of time values, ability to vary route, freedom to choose stopping places. There would be a range of vehicle sizes operating simultaneously on many routes; at the extremes, some routes would only be served by conventional buses, and some only by small vehicles.

In London significant congestion on main routes might be caused by either
### TABLE 1

Traffic Congestion: High Flows  
Changes relative to Figure 2

<table>
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<th>Figure</th>
<th>Big Bus Flow</th>
<th>Small Bus Flow</th>
<th>Net Bus Change$^a$</th>
<th>Passenger Flow</th>
<th>Car/Taxi Change$^b$</th>
<th>Speed Change$^c$</th>
<th>Break Even$^d$</th>
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### TABLE 2

Traffic Congestion: Medium Flows  
Changes relative to Figure 6

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<th>Net Bus Change$^a$</th>
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<th>Car/Taxi Change$^b$</th>
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</tr>
<tr>
<td>8</td>
<td>17</td>
<td>122</td>
<td>+191</td>
<td>+694</td>
<td>-68</td>
<td>-0.80</td>
<td>38</td>
</tr>
</tbody>
</table>

$^a$ Assumes 1 big bus = 2 passenger car units (pcu); 1 small bus = 1.5 pcu.

$^b$ Assumes that of the new bus passengers, 13.7% have transferred from car or taxi. Source: Beesley, Gist and Glaister (1983); average of tables A1.1 and A1.2.

$^c$ Assumes London speed flow slope of -0.00646 mph/pcu. For Provincial Metropolitan County the slope would be -0.003, so speed changes would be about one half.

$^d$ The proportion of new bus passengers that would have to come from car and taxi if speeds were not to change.
reducing subsidies or allowing a proportion of big buses to be replaced by smaller ones. The extent of disbenefits from the smaller buses depends upon how far the improved service quality offered, especially to those with high time values, succeeds in seducing private car and taxi users on to vehicles carrying more passengers. The congestion caused would generally be less significant in the metropolitan areas and other large towns.

REFERENCES


