THE CHOICE BETWEEN
CARS AND BUSES ON URBAN ROADS

By C. H. Sharp

One measure which would help to relieve congestion on urban roads would be for more people to travel by bus and fewer by private car. A car-to-bus transfer on a significant scale is not likely to be brought about by persuasion; it would almost certainly require some form of state intervention through taxation, parking policy or direct restrictions on private cars. This means that it is necessary to be able to justify interference with the free choice made by car travellers and to find some criterion for discriminating between those roads, or urban areas, where action is warranted and those where it is not. It is these related problems with which this discussion is concerned.

It is a widely accepted claim of transport policy\(^1\) that the trend from public to private transport ought to be halted or reversed. This, of course, is because buses normally use less road space per passenger than do private cars. In calculations relating speed to the volume of traffic flow a bus is generally estimated to be the equivalent of 3 "passenger car units". With average car loads of approximately 1.5 persons on urban roads in peak periods, this means that any bus with an average load of more than 4.5 passengers is using less road space per passenger than a private car. At this level of loading buses would be less efficient than cars when the other scarce resources of labour and capital equipment are considered (i.e. their total costs per passenger mile would be higher), but at normal peak period loads of about 40 passengers for a double-decker bus they would easily be the more efficient operators. Since urban road space is already generally congested, and as it is extremely unlikely that the supply of extra road space will keep up with the growth in traffic in the next five or ten years, the \textit{prima facie} case for a greater use of buses is very strong. But this leaves out of consideration the very important issue of quality of service. The continued changeover from public to private urban transport in Britain in recent years suggests that the car, even at a higher price, is preferred as a form of transport to the bus. The reasons for this preference may be complex, and may differ for different individuals; but it seems reasonable to assume that as far as the journey to work is concerned the outstandingly important factor is the length of "door to door" journey time. In their pioneering study Wardrop and Smeed showed that even in Central

\(^1\)See for example the discussion in \textit{Transport Policy}, para. 66, Ministry of Transport.
CARS V. BUSES ON URBAN ROADS

January 1967

London total car journey time averaged only half total bus journey time for distances of 3 to 5 miles.\(^2\)

There are three reasons for the car advantage in total door-to-door journey time. The bus "terminal" times will consist of the walk from a passenger's house to the bus stop, the wait for the bus, and the walk from the bus stop to the ultimate destination at the other end of the journey. Car terminal times involve getting the car out of the garage at the beginning of the journey and parking it and walking to the destination at the other end. Despite the worsening parking conditions, it is almost certainly true that for most people in most places the bus terminal times remain much longer than car terminal times. Secondly, the "vehicle journey speed" of the car on the journey will usually be higher than that of a bus. There is, unfortunately, a lack of reliable figures on the difference between bus and car vehicle speeds in relation to congestion levels. Generally it may be expected that the speed advantage of cars will get smaller with increasing congestion, and may eventually disappear altogether. The situation will, of course, vary considerably on different roads according to the number of bus stops per mile and the degree of difficulty involved in overtaking. A third, and usually less important, advantage of cars is that the total door-to-door distance may be shorter than when the journey is made by bus.

If average door-to-door journey time is at present nearly always shorter by car than by bus, then a policy aimed at securing a car-to-bus transfer needs some justification other than that of the superior road utilisation obtained from buses. Still higher road utilisation could be obtained from the use of Nigerian mammy wagons with forty people perched in the back of a converted lorry, but they may be supposed to have more than compensating disadvantages. A car-to-bus transfer policy can most easily be justified if it can be shown that it would result in shorter door-to-door journey times for everyone. Suppose that on a uniformly congested road \(X_S\) passengers travel by bus and \(X_c\) by car, both at a vehicle speed of \(S\) miles per hour, that bus passengers' average terminal time is \(z\) minutes and that of car passengers is \(\beta\) minutes (where \(z > \beta\)), that the transfer of \(\Delta X_c\) car travellers to buses would result in a speed increase of \(\Delta S\) m.p.h., and that the average length of journey of both bus and car passengers along the congested road is \(L\) miles. Then so long as the saving in vehicle journey time of the transferred travellers

\[
\frac{60L}{S} - \frac{60L}{S + \Delta S}
\]

is greater than the loss of "terminal" time \((z - \beta)\) everyone must gain, since both the original bus passengers and the "continuing" car passengers will have shorter journey times. Now if the supply of road space is assumed to be fixed, and if the present trends of growing car ownership and of bus-to-car passenger transfers are continued into the future, it becomes increasingly likely that the condition described above, that everyone's door-to-door journey time would be reduced by a car-to-bus transfer, will be fulfilled. As the average traffic flow speed \((S)\) becomes smaller the proportionate increase in speed resulting from a reduction in the total traffic flow

\[
\frac{\Delta S}{S}
\]

is likely

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\(^2\)R. J. Smeed and J. G. Wardrop, "An Exploratory Comparison of the Advantages of Cars and Buses for Travel in Urban Areas", *Institute of Transport Journal*, March 1964. This comparison was itself partly based on a study by E. Holroyd and D. Scraggs of the Road Research Laboratory, now published as "Journey Times by Car and Bus in Central London", *Traffic Engineering and Control*, 1964, 6, (3), 169-173.
to become greater, while the “terminal” time difference will remain constant. Eventually S would equal zero and any increase in it would be infinitely great.

Given the continuance of present trends, then, a car-to-bus transfer can be justified as a policy objective, on the reasonable grounds that eventually all travellers would enjoy time savings. But there are many congested roads in Britain, probably the great majority, where the condition of universal time savings from an immediate car-to-bus transfer does not yet exist. A more immediately applicable criterion would be to hold that a “compulsory” transfer is justified where it would result in the reduction of the total door-to-door journey time of all passengers using the road. This “total journey time” criterion depends upon a value judgment. It cannot be justified by formal welfare criteria, since no allowance is made for different valuations of time savings by different individuals. The “losers”, if this criterion were applied (leaving aside all questions of compensation by a lower price, and considering only time savings or losses), would be those people who were transferred from car to bus, while “original” bus passengers and “continuing” car travellers would gain.

Assuming that only city centre bus or car commuters used the road, retaining for the moment the assumption that buses and cars had the same vehicle speed, using the symbols already introduced, and denoting the pre-transfer total door-to-door journey time in minutes by $T_1$, this would then be given by

$$T_1 = \frac{(X_b + X_c)}{S} + \alpha X_b + \beta X_c$$

and the post-transfer journey time, $T_2$, would be given by

$$T_2 = \frac{(X_b + X_c)}{S + \Delta S} + \alpha (X_b + \Delta X_c) + \beta (X_c - \Delta X_c)$$

The net change in total door-to-door journey time ($T_1 - T_2$) would therefore be

$$T_1 - T_2 = X_b + X_c \left( \frac{60L}{S} - \frac{60L}{S + \Delta S} \right) + \Delta X_c \left( \beta - \alpha \right)$$

In the rather more complex case where car vehicle speeds are greater than bus vehicle speeds, by an assumed constant $i$ (but where the speed increase from the car-to-bus transfer is the same absolute amount, $\Delta S$, for both cars and buses), the change in total door-to-door journey time will be given by

$$T_1 - T_2 = X_b \left[ \frac{60L}{S} - \frac{60L}{S + i + \Delta S} \right] + X_c \left[ \frac{60L}{S + i - \Delta S} - \frac{60L}{S + i + \Delta S} \right] + \Delta X_c (\beta - \alpha)$$

This formula is still simplified in that the bus/car modal split is assumed to be constant over the whole length of the congested road, and all traffic other than commuter cars and buses is ignored. Nevertheless it is instructive to quantify it with figures representing realistic conditions. The initial values of the various parameters were taken as being:

- $L = 3$ miles
- $X_b = 3500$ m.p.h.
- $S = 10$ m.p.h.
- $X_c = 2380$ m.p.h.
- $i = 6.7$ m.p.h.
- $\beta = 5$ minutes
- $\alpha = 10$ minutes

\(^3\text{Cf. p. 110 below.}\)
CARS v. BUSES ON URBAN ROADS

January 1967

All these figures, with the exception of $\Delta S$, were estimated from traffic flow and bus occupancy data relating to radial roads into central Leicester at peak periods. An arbitrary value for $\Delta S$ of 1 m.p.h. was then chosen, and the value of $\Delta X_c$ calculated when $T_1 - T_3 = 0$. For $\Delta S = 1$ the value of $\Delta X_c$ for this "breakeven" point was 641 and for $\Delta S = 5$ it was 3092. This means that according to the "total journey time" criterion a movement of passengers from car to bus would be justified, so long as an increase of traffic flow speed of 1 m.p.h. could be achieved by a transfer of less than 641 passengers. If the ratio $\Delta S : \Delta X_c$ (for $\Delta S = 1$) was greater than 1 : 641 a transfer of passengers to bus would increase the total journey times, since the gains of the original bus passengers and the "continuing" car travellers would be more than offset by the losses of the car-to-bus transferees.

The effect of changing the values of $i$ (the difference between bus and car vehicle speeds) and $L$ (the average length of journey on the congested road) can now be considered. In eight trial journeys made during peak periods from departure points chosen at random outside central Leicester to different places in central Leicester (and vice versa) the average vehicle speed of the buses was 11.4 m.p.h. and that of the cars was 16.58 m.p.h. But the variation in relative speeds was very considerable. For bus speeds the standard deviation was 3.3 m.p.h. and for car speeds 9.5 m.p.h. The comparable off-peak vehicle speeds for 11 journeys were 13.28 m.p.h. ($\sigma = 2.6$) and 22.36 m.p.h. ($\sigma = 4.2$) respectively. Table I shows the "breakeven" number of passengers who could be transferred from car to bus for a 1 m.p.h. increase in the average speed of the traffic flow, according to the total journey time criterion.

Table I. Number of passengers per hour transferring from car to bus, with a 1 m.p.h. increase in average traffic flow speed, for a total journey time "breakeven" position.*

<table>
<thead>
<tr>
<th>$L$</th>
<th>$3$ miles</th>
<th>1 mile</th>
<th>0.5 miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i = 10$ m.p.h.</td>
<td>527</td>
<td>296</td>
<td>178</td>
</tr>
<tr>
<td>9</td>
<td>554</td>
<td>306</td>
<td>184</td>
</tr>
<tr>
<td>5</td>
<td>743</td>
<td>373</td>
<td>214</td>
</tr>
<tr>
<td>4</td>
<td>829</td>
<td>401</td>
<td>226</td>
</tr>
<tr>
<td>2</td>
<td>1127</td>
<td>483</td>
<td>261</td>
</tr>
<tr>
<td>1</td>
<td>1410</td>
<td>548</td>
<td>286</td>
</tr>
<tr>
<td>0</td>
<td>1924</td>
<td>641</td>
<td>321</td>
</tr>
</tbody>
</table>

* $X_c = 2380; \alpha = 10$ mins; $\beta = 5$ mins.

$X_0 = 3900$.

As would be expected, the position becomes worse (in the sense that a 1 m.p.h. increase in traffic flow speed must be achieved with a smaller transfer of passengers) as the average length of journey on the congested road becomes shorter and as the vehicle journey speed advantage of cars becomes greater. Thus when $L = 0.5$ and $i = 10$ m.p.h. it must be possible to achieve an increase in average traffic flow speed of 1 m.p.h. for the transfer of only 178 passengers in order to achieve the "breakeven" position. For $i = 0$ and $L = 3$ miles the breakeven figure increases to 1,924 passengers. These low and high breakeven figures represent 7.5% and 80-8% respectively of all passengers originally travelling by car.

4These data, and other figures used in this discussion, were collected during a survey of passenger transport in the Leicester area on which the author, working on behalf of the East Midlands Regional Planning Board, is currently engaged.
The average terminal time for 11 journeys made by bus in Leicester was 14·2 minutes. The average terminal time for the same journeys made by car was 10·7 minutes if car parking time was 3 minutes, and 13·7 minutes if parking time was 6 minutes. Table II shows the breakeven car transfer figure for any length of journey, when $\alpha = \beta$.

**Table II. Number of passengers per hour transferring from car to bus, with a 1 m.p.h. increase in traffic flow speed, for a total journey time "breakeven" position, when bus and car terminal times are the same**

<table>
<thead>
<tr>
<th>$i$ (m.p.h.)</th>
<th>&quot;Breakeven&quot; transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>866</td>
</tr>
<tr>
<td>9</td>
<td>931</td>
</tr>
<tr>
<td>5</td>
<td>1469</td>
</tr>
<tr>
<td>4</td>
<td>1780</td>
</tr>
<tr>
<td>2</td>
<td>3365</td>
</tr>
<tr>
<td>1</td>
<td>6578</td>
</tr>
<tr>
<td>0</td>
<td>$\infty$</td>
</tr>
</tbody>
</table>

* $X_b = 3500; X_c = 2380; \alpha = \beta$.

The question now arises how far the speed increases required to justify a car-to-bus transfer according to the total journey time criterion are attainable. The speed/flow relationship obtained by the Road Research Laboratory for central London roads in 1962 fits recent data for the relationship on roads in central Leicester fairly closely. This relationship (applying to speeds of 24 m.p.h. or less) is expressed in the linear equation

$$V = 28 - 0.00583 Q$$

where $V$ is the average speed of cars in the traffic flow and $Q$ is the number of vehicles per hour (in passenger car units). If an average car load of 1.4 and an average peak bus load of 45 are assumed, and the adapted speed/flow equation

$$V = 28 - 0.00583 \left[ \frac{3X_b}{45} + \frac{X_c}{1.4} \right]$$

is held to apply, then the transfer of 641 travellers from bus to car would increase average vehicle journey speeds by 2.4 m.p.h., so that the car-to-bus transfer would be justified on this criterion. If the average length of journey on the congested road, $L$, was only 0.5 miles the breakeven value of $\Delta X_c$ would be 198·3 passengers, and if $L = 1$ mile it would be 338·4 passengers. A car-to-bus transfer of 199 would give a speed increase of 0·8 m.p.h. and one of 339 passengers an increase of 1·3 m.p.h., so that the first transfer would bring a net increase in total door-to-door journey time, the second a small decrease.

The assumed speed/flow equation gives a speed increase of 1 m.p.h. ($\Delta S = 1$) for every 265 passengers transferred from car to bus. This means that, of the possibilities

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5Parking time here means literally the time spent in the car park. The time for walking between the nearest car park and destinations in central Leicester was measured separately.
7This formula was used for the first estimate of the value of $i$ above ($i = 6.7$), given an average bus speed of 10 m.p.h. and a traffic flow of 1933 passenger car units.
examined in Table I, the only cases where a car-to-bus transfer would not be justified (because the required speed increase could only be obtained by moving more than the breakeven number of passengers) are where $L = 0.5$ miles and $i \geq 4$ m.p.h. All the possible transfers in Table II, where $a = b$, would be justified.

The speed/flow formula used does not, of course, apply to all traffic conditions; generally for worse conditions the gain in speed (both as an absolute amount and as a percentage increase) from a given reduction in the traffic flow will be greater. The journey time formula used here assumes that both bus and car speeds will increase equally if the traffic flow is reduced (although different values have been given for the difference, $i$, between car and bus vehicle speeds, it is assumed that $i$ remains constant after the car-to-bus transfer). But this assumption may not be justified for large speed increases, when the value of $i$ may also increase. This means that continuing car travellers would gain more in reduced journey time than bus passengers, and the effect of a transfer on total journey times could be affected by the initial distribution of passengers between car and bus, savings of journey time being greater, $et	ext{ à} l	ext{ ès}$, the higher the original proportion of car travellers was to all travellers. The dropping of the assumption that the traffic flow is composed entirely of buses and of cars carrying commuters need not have a drastic effect on the calculations of journey time savings. Suppose that two new categories of travellers, commercial vehicle (including lorry) drivers and through car travellers, were introduced. Then these would constitute a part of the traffic flow which could not be transferred to local buses, but they would benefit from increased traffic speeds in the same way as post-transfer car travellers. The inaccuracies resulting from including these classes of road users with car commuters, as has been done in the calculations made in this article, are that the car load figure of 1.4 is too high for both lorries and commercial vehicles, and that lorries are equivalent to more than one passenger car unit.

The practical implications of the use of the total journey time criterion can only be very tentative, since its application involves detailed knowledge of the conditions on individual roads. Preliminary work in Leicester suggests that there may at present be only comparatively short lengths of road, of 0.5 to 1.0 mile, where the conditions represented in the calculations made above apply. There are probably only short and irregular peak periods during which a general car-to-bus transfer would bring about marked reductions in total journey time. The Smedd and Wardrop study showed that a transfer of all car travellers to buses in central London conditions would increase average (and therefore total) journey times for journeys of 1 mile or less with parking times of less than 8 minutes. For 3 mile journeys average journey times would decrease by 4% if parking time was zero and by 11% if it was 10 minutes.

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8Given a linear relationship $V = a - bQ$ the value of $b$ will be greater for narrower roads or those with more intersections. Thus Wardrop's 1947 formula for all traffic on 30 ft. roads in central London was

$$V = 25 - 0.014Q$$

The allowance for controlled intersections made by Smedd and Wardrop in the Central London study increases the value of $b$ to approximately 0.0059 for the range of traffic flows to which a linear relationship is applicable.

9Smedd and Wardrop, op. cit., page 110.
If the various problems of measurement discussed here could be overcome, would the criterion of reduced total door-to-door journey time be an acceptable policy guide? Perhaps the main theoretical difficulty is that there is no weighting of time savings, those of all travellers being valued equally. Some people value time savings more than others, and if one of the three classes of travellers (original bus passengers, continuing car travellers and car-to-bus transferees) put a larger or smaller average value per minute on its time savings than the others the calculations of net benefit would be affected. It could be argued that those willing to pay more to travel to work more quickly by car value their time savings more than those using buses. If a tax were to force some car users into buses, it would follow that those still using cars would be those willing to pay more for the speed advantage. As has been argued elsewhere in discussing the case for a general congestion tax, however, willingness to pay will mainly reflect income levels, and it depends on our value judgments whether this is taken to be an adequate measure of the value of time savings to the community.\(^8\) Weighting time savings by some willingness-to-pay or consumers'-surplus type criterion would probably give the greatest weight to continuing car travellers, the next largest weight to car-to-bus transferees, and the smallest to original bus passengers. The net effect of such weighting is impossible to estimate except with specific figures, as the losses (increased door-to-door journey times) of the car to bus transferees, and the gains of the continuing car travellers, would both be made more important. The use of a form of congestion tax or of increased parking charges as a means of bringing about the transfer would be more efficient than an undiscriminating ban on private cars, because it would allow some choice between bus and car travel according to individual evaluations of time savings.

In making estimates of the gains from a car-to-bus transfer, however, it would not seem to be worth while to try to put different values on the time savings of different people when almost all of them will be making work journeys. A system of weighting (apart, that is, from the “automatic” weighting according to income which would result from the unquestioning use of the price mechanism envisaged by some advocates of a congestion tax) would be complicated, could only be based on very imperfect information, and would not yield any great advantage.

There is another main problem in using the reduction of total door-to-door journey times as a criterion for the justification of mandatory action designed to bring about a car-to-bus transfer. This arises when the dynamic rather than the static situation is considered. If present trends continue the value of the parameters of the measuring equations will change constantly, and, as has already been argued, they will tend to make the time savings from a transfer greater. The policy issue therefore arises of how far ahead of the trends mandatory action to secure a car-to-bus transfer would be justified. To wait until conditions had deteriorated to the point at which a transfer would be justified on the reduced-journey-time criterion could be to wait too long. By this time public transport might be so run down that it could not be quickly or easily expanded again to take the transferred traffic. On the other hand, to act too soon would obviously be unjustified. This problem is closely related to the important issue, which is largely outside the scope of the present discussion, of the means by which

the transfer would be secured. It is obviously more difficult to discriminate between different roads if parking restrictions are the chosen method of control than if a form of congestion tax is used. If parking restrictions were the main method of bringing about a transfer, then the effective choice of where to induce a car-to-bus transfer, and where not to, might lie between different urban centres rather than between individual roads. Nevertheless the journey time criterion could be used and the results for different routes aggregated. A complication connected with parking restrictions is that a change in these would itself affect the relationship between a car-to-bus transfer and total journey times.

A transfer of travellers from car to bus is one of the few measures which would lead rapidly to a significant improvement in the level of congestion on urban roads. A measurement of the effect on total journey time seems to be the most straightforward criterion for distinguishing between those road conditions on which “compulsory” methods of transfer should be applied, and those where they are not yet appropriate.

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