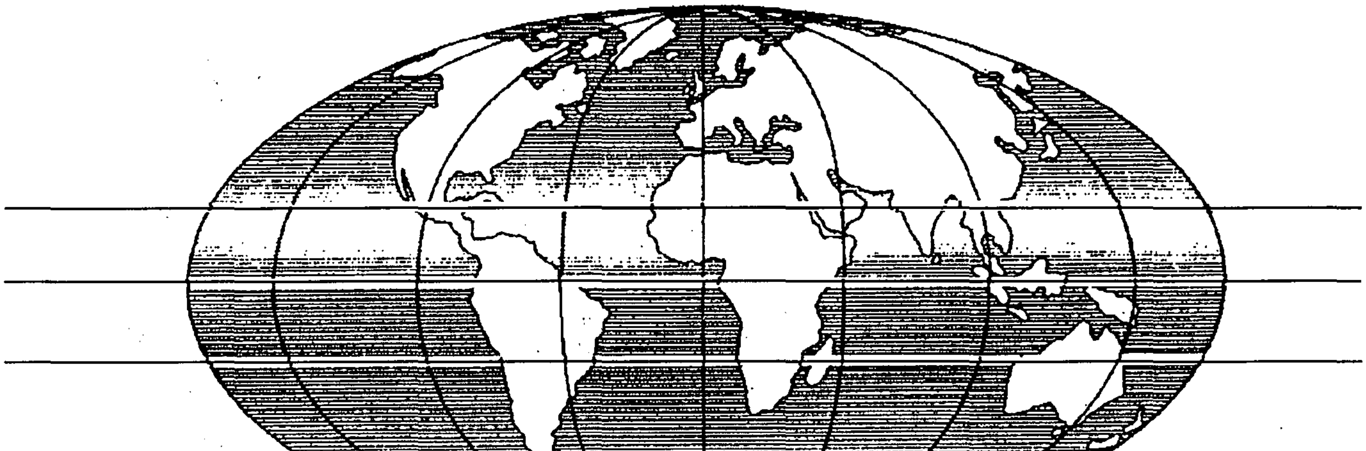
TRANSPORT RESEARCH LABORATORY

TITLE Analysis of the effect of bus size on route performance

by S Vijayakumar and G Jacobs



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DRIVE and DRIVE 2

A joint TEG/IEE meeting was held in London early last month to discuss the benefits of U.K. involvement in the EC's DRIVE research programme, now a full two years into its three-year course, and the opportunities for participation in its successor, DRIVE 2.

Keith Keen from the programme's Brussels office first described the structure and aims of DRIVE, to be achieved by the development of a common European environment of better-informed drivers who interact with the road infrastructure. The 71 projects in the programme are divided into four groups — general approach and modelling; behavioural aspects and traffic safety; traffic control; and services, communications and databases — each carried out by an international consortium made up of universities, consultancies, industrial companies and government agencies. The consortia meet four times a year, with SECFO, the System Engineering and Consensus Formation Office, having the rôle of bringing together all the technical outputs and producing a consensus on the promotion of such technologies to outside organisations (users, industry and standards bodies).

Ian Catling then highlighted the level of U.K. participation in DRIVE, with 41 U.K. organisations involved — bettered only by Germany, with 43 — and the U.K. being prime contractor (consortium leader) in 19 of the 71 projects, more than any other member state. These latter projects cover areas such as accident analysis and prevention; incident detection and congestion management; technological developments such as cellular radio, digital maps and that required for road pricing; the human response; urban modelling; and pollution. Breaking down the U.K. involvement by type of organisation, it was seen that the major contributors were universities (13) and consultancies (10), with only eight from industry. This was contrasted with Germany and France, with a similar total number of contributors but an industrial involvement which was nearly twice as high as that of the U.K. In particular, neither the automotive industry nor the electronics and supply industry have any U.K. representation in DRIVE.

Looking to the advantages and costs of involvement in DRIVE, Mr Catling identified two key issues. Firstly, the potential for commercial exploitation of the research work, towards which many of the projects have been working. There are, however, a number of projects — particularly in the general modelling and behavioural safety groups — where the commercial gain is less easy to identify, and these tend to be projects where university participation is the greatest. Secondly, financing depends on the type of institution, with academic research institutes receiving 100 per cent of their marginal costs (that is, the full cost of recruiting staff specifically for DRIVE, but not the cost of any permanent staff), whereas industrial participants receive 50 per cent of total costs. This may have been a major reason for the reluctance of the larger British companies to get involved — although the initial signs are that a number of new industrial partners are emerging across Europe for DRIVE 2. It was seen as a major advantage that partners own the intellectual property rights for their research, but two speakers commented on the difficulty of obtaining participation from U.K. industry in DRIVE projects.

Continued on page 660

Analysis of the effect of bus size on route performance

by S. Vijayakumar*
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This paper describes a Bus Route Simulation Model which can be used to assess the performance of a bus route when operated by vehicles of different sizes. The model is used to examine various operating policies on a candidate route. The analysis is extended to other types of route to see whether specific conclusions for one route can be applied to others. The analysis is not exhaustive, but serves simply to show the capability of the model.

1. INTRODUCTION

The Bus Route Simulation Model was developed by Vijayakumar[1] at Imperial College, London, and the Overseas Unit of the Transport and Road Research Laboratory. The model can replicate a complete day's operations of a specified bus route. Using information which describes the characteristics of the route, the buses on the route and the passengers using the route, the model can be used to determine various performance characteristics of that bus route system, as well as the costs of operating the route.

This paper outlines the structure of the model, its data needs and its capabilities, and also describes some examples of its use to examine the performance of a bus route and the implications of changes in bus operating policies when the route is serviced by vehicles of varying size. This analysis is partly extended to two other routes to see to what extent specific conclusions for one route can be applied to others. The sensitivities of some of the model assumptions are also critically examined. The purpose of this paper is not to provide definitive guidelines on route operations, but to demonstrate the capability of the model and areas for future applications. Route information from the Delhi Transport Corporation has been used to test and validate the model.

The simulation model is structured such that movement of every bus from stop to stop along a route can be represented. The important model components (such as passenger boardings and alightings, bus running times, etc.) can only be defined at bus-stop level, and thus monitoring of bus performance is most easily undertaken at the same level.

The primary objective of the model is to describe the level of service provided by a specified vehicle fleet of given operational characteristics running over a single route subject to a fixed travel demand, albeit varying over the time of the day. In order to describe the level of service and the associated cost of providing it, the main outputs from the simulation model are:

- total route operating costs;
- total travel times of passengers using the route; and
- total wait times of passengers using the route.

To provide these outputs the model therefore needs to accumulate information on wait time, in-vehicle time and total operated bus kilometrage. In order to accumulate the necessary information the model scans the activities of both passengers and buses at each bus-stop during each second (or other specified time unit) of the simulation. The model therefore has to be capable of representing both the arrival of passengers and of buses at stops, as well as the subsequent departure of those passengers whether they board the next bus or one of those following. A passenger is in the system from the time of his arrival at a bus-stop until the time of alighting at his chosen destination. Thus each passenger has to be monitored throughout this time period and the 'wait' and 'ride' times for every passenger are cumulated to give total travel in the system.

2. MODEL INPUT

The data which need to be input to the model consist of three broad types:

- characteristics of the route and its operation;
- characteristics of the bus fleet; and
- characteristics of the passengers.

Much of the data is based on survey information and is contained in an input file, although some data are contained within the model in the form of functional relationships. Some of the input date are time-dependent in that they vary between different specified periods of the day.

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*This paper describes some of the work undertaken by Dr Vijayakumar for his doctoral dissertation at Imperial College, London.

The model contains a number of functional relationships which enable inter-stop travel times, time lost by buses at stops, passenger generation at stops, passenger destination, operating costs for buses and trip revenues to be calculated from the input data.

2. 1. Inter-stop running function

Running time between bus-stops can be expressed as a probability distribution, e.g. a shifted gamma distribution, which caters for unpredictable delays and congestion. However, for the routes surveyed in Delhi it was found that the variation in running times was small for each time period and the values were symmetrical around the mean. Consequently a normal distribution was used to generate the running times between stops for each different time period. This distribution is determined by its mean value and standard deviation, which were observed in survey work.

2. 2. Lost time function

Many studies, e.g. Pretty and Russell[2], have shown that lost time at stops tends to vary linearly with the number of boarding and alighting passengers. If no passengers either board or alight at a stop then the lost time is zero. Relevant lost-time equations were estimated from survey data. Specifying the type of bus (minibus, single- or double-deck) controls the appropriate boarding and alighting time relationship used in the simulation.

2. 3. Passenger arrival at stops

Passenger arrivals are essentially dependent on the frequency of service. However, it is normally assumed and supported by observation (Danas[3]) that when bus frequency is relatively high, arrivals form a Poisson process.

2. 4. Passenger destination

The number of passengers alighting at any stop can be modelled in a variety of ways depending on the quality of the data that are available. Ideally full information on boarding and alighting patterns should be available, but from the Delhi surveys information was available only on the numbers of passengers boarding and alighting at each bus-stop. Consequently a multiple linear regression model was developed so that the conditional probabilities of passengers alighting at a stop j, given that they had boarded at stop i, could be estimated. Thus the numbers of passengers alighting at any stop could be allocated to boarding points on the basis of these conditional probabilities.

2. 5. Cost functions

The measures of output used for formulating a simple cost model for the Delhi Transport Corporation (DTC) were restricted to numbers of buses used and kilometrage run. The model can be expressed very simply as:

$$TC = FC + b_1K + b_2V$$

Where TC is the total daily operating cost, FC is the fixed-overhead cost per day, K is the daily kilometrage output of the fleet, V is the number of vehicles in use per day, b_1 is the cost per km and b_2 the cost per vehicle employed. Thus b_1K is the direct cost and b_2V the variable overhead cost of the DTC as a whole.

The daily cost C of an individual vehicle, exclusive of any fixed-overhead component, is given by the following equation, where K is the daily output per vehicle:

$C = b_1K + b_2(V = 1)$

This equation was used in applications of the cost model since only incremental changes in output level were being considered, which would be unlikely to have any effect on the fixed cost component. On this basis the daily cost (in *paise*, where 100 *paise* = 1 Rupee and 15 Rupees = £1) to the DTC of operating a single-deck, double-deck or minibus was found to be:

- single-deck
  $C_S = 22\,400 + 93\,K_S$
- double-deck
  $C_D = 31\,100 + 133K_D$
- minibus
  $C_M = 17\,400 + 93K_M$

where K_S, K_D and K_M are the daily kilometrages run by each vehicle type (single, double, mini). These equations represent conditions where a vehicle is used throughout the day (on two shifts). They can be modified to represent the case where vehicles are used only in the peak (one split shift) as follows:

- single-deck (peak only)
  $C^P = 17\,400 + 93\,K^P$
- double-deck (peak only)
  $C^P = 26\,100 + 123\,K^P$
- minibus (peak only)
  $C^P = 15\,000 + 91\,K^P$

All these equations enable specification of the type of bus, and whether it is a peak vehicle or all-day vehicle, to control the selection of the appropriate cost equation.

3. MODEL OUTPUT

The output from the model can be classified into three basic groups:

- output relating to bus performance;
- output relating to the service received by passengers; and
- output relating to the overall performance of the route.

As with the input data, some of the output data can be produced for individual time periods or for the complete day's operations. Some output data are also produced for individual buses and for individual bus trips. Table I presents the full output data from the model.

4. VERIFICATION AND VALIDATION

The process of verification and validation of the model is described in Vijayakumar[1] where it was concluded that 'the model performed well on all the tests on the two sets of (trial) input data. The reasonable assumptions and the flexibility in representing varied conditions give further confidence that the model is valid for a broad range of content'.

5. OPERATING COST ANALYSIS

5. 1. Current conditions

The first runs of the model were with existing demand data for Route 80 of the Delhi Transport Corporation[4], varying the number and size of buses in use.

Table I. Data output from the simulation

Output type	Description
Bus performance	Bus journey times for each trip (min.) Total bus-km for each bus Passengers carried by each bus on each trip Number of trips by each bus Load factor for each bus trip Average load factor for each bus over whole day, by direction of travel Average journey time for buses Revenues collected in each period by bus Total revenue for whole day by bus Total operating costs for whole day by bus
Service level	Average wait times at each stop by period (min.) Total passengers travel and wait times for each direction (min.) Overall average wait time and ride time of passengers (min.)
Route performance	Total passengers demand at each stop for each period Total alighting passenger at each stop for each period Total daily demand in each direction Average passenger journey length (km) Average travel time (min.) Average wait time (min.) Revenues collected Running costs Profit

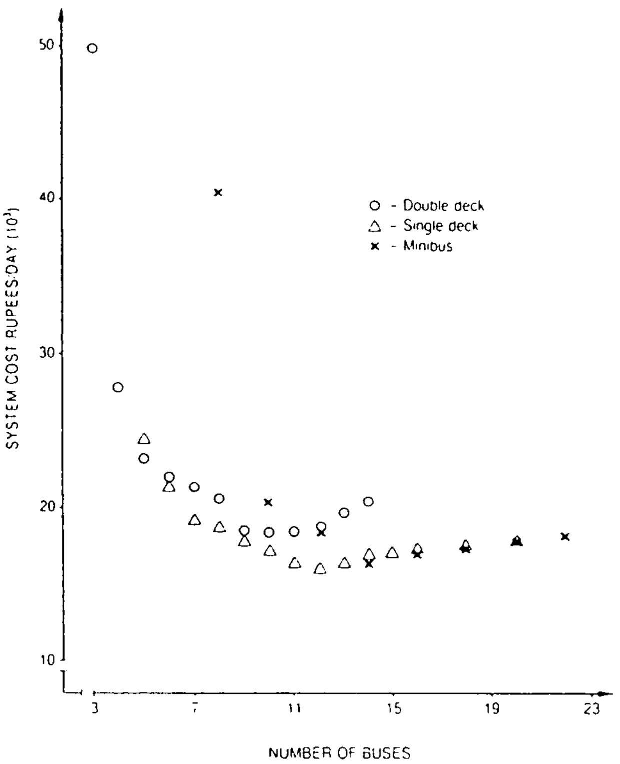

Fig 1. System cost against number of buses (current demand level, Route 80).

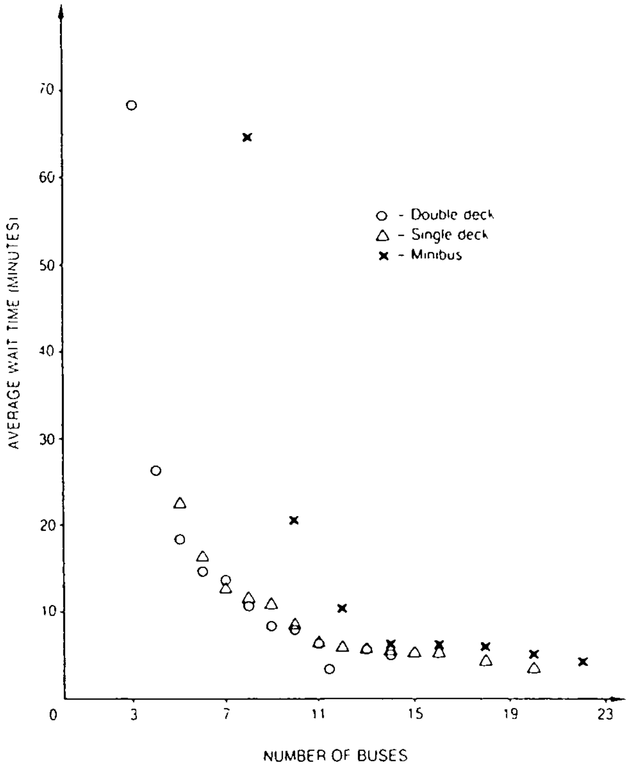

Fig 2. Average waiting time against number of buses (current demand level, Route 80).

The three curves in Fig 1 have a characteristic and similar 'U' shape. Thus, costs are high for small numbers of vehicles, reflecting both the high waiting times that travellers will experience with a low frequency of operation as well as the high probability of being unable to board one or more buses. Overall ride times will also be enhanced because of the additional delays at bus-stops caused by large numbers of passengers boarding and alighting from each bus. However, as the numbers of vehicles is increased, so waiting times and, to a lesser extent, ride times are reduced and the cost curves decline. Waiting-time savings are generally substantially larger than the additional costs of the extra buses. (N.B.: In this first example, waiting times and riding times have been valued at the same rate.)

Figure 1 shows that a minimum point is reached, beyond which costs begin to increase. This point occurs when additional buses cost more to run than the benefits of reduced waiting times. Thus the rate of improvement in waiting times diminishes as more vehicles are deployed; passengers have a very low probability of having to wait for more than one bus and waiting times are a simple function of bus headways.

Figure 1 also shows that the minimum system cost for each bus type is related to bus size: generally the smaller the vehicle, the more of them are required to achieve a minimum total system cost. Thus, using double-deck buses on Route 80, something like 10 vehicles would be needed to meet current demand levels at minimum system cost for that vehicle type. Similarly 12 single-deck buses or 14 minibuses would be needed to achieve a minimum system cost, if these vehicle types were to be used to fulfil current demand levels on Route 80. Comparison between vehicle types shown in Fig 1 indicates that the single-deck buses can achieve a marginally lower total system cost than other bus types. By comparison, double-deck buses perform relatively badly on this route.

5.2. Cost sensitivities

The model was re-run, varying some of the input data for Route 80 to assess how sensitive the system costs are to various assumptions.

Table II contains a summary of this sensitivity analysis. It shows how system costs vary (measured from the minimum system cost under current conditions) with changes in some key variables. Perhaps not surprisingly, system costs are most sensitive to demand. Increasing demand has a greater effect on system costs than does decreasing demand. Furthermore, the effect is pronounced for both double-deck buses and minibuses. It would appear that under these conditions double-deck buses are adversely affected by long headways, and hence high wait times for passengers unable to board the first arriving bus; minibuses are adversely affected by a limit on available space for passengers wanting to board along the route. Once filled at the terminals, there is no room for any further boardings along the route.

Table II. A summary of the main results from the sensitivity analysis undertaken for Route 80

Variable	Range of variations* (per cent)	Resultant range of variation in system cost** (per cent)		
		Double-deck	Single-deck	Minibus
Demand level	+ 50 - 50	+ 86 - 44	+ 53 - 43	+ 87 - 36
Travel time weight	+ 100	41	28	22
Value of time	+ 50 - 50	+ 42 - 42	+ 30 - 30	+ 20 - 20
Speed of buses	+ 10 - 10	- 18 + 31	- 12 + 8	- 7.0 + 7.5
Bus operating costs	+ 10 - 10	+ 1.5 - 1.5	+ 2 - 2	+ 4 - 4

* Measured about current operating conditions

** Measures as a deviation from the minimum system cost under current conditions (Section 5.1)

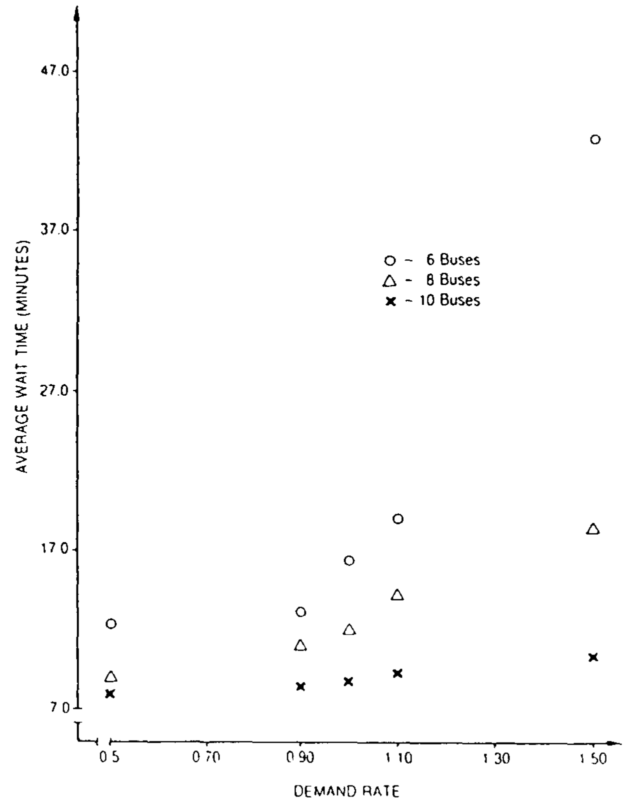

Fig 3. Average waiting times against demand rate for different numbers of single-deck bus (Route 80).

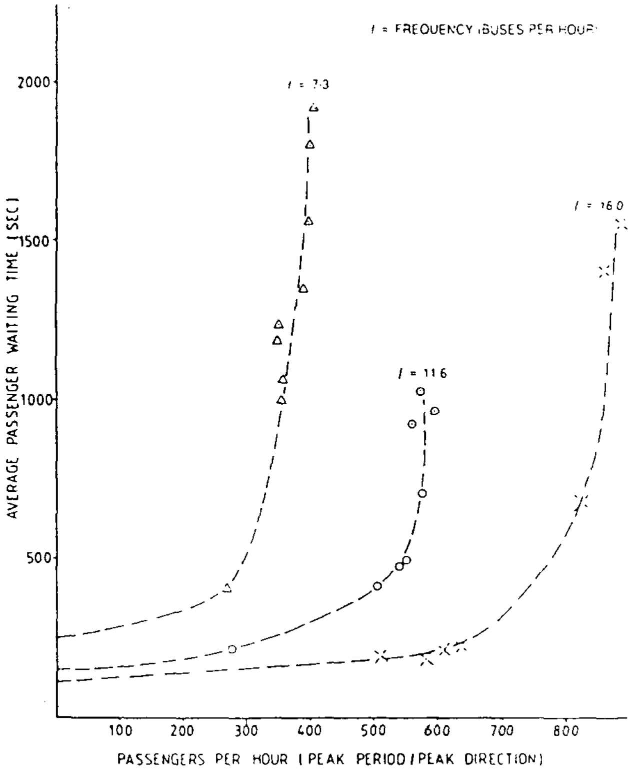

Fig 4. Average waiting times of passengers against the number of passengers using the system (minibus).

Changes in travel-time weights and value of time are somewhat more critical for the larger buses, because operating costs are a larger component of system costs. Changing the weight ratio from 1:1 (wait:ride) to 2:1 increases double-deck system costs by 41 per cent compared with 22 per cent for minibuses. Similarly, increasing the value of time by 50 per cent pushes up double-deck system costs by 42 per cent as against a 20 per cent increase for minibus system costs. For the same reason, changes in the unit operating costs of buses have a greater effect on minibuses than larger buses.

Changes in the speed of buses have a greater effect on double-deck buses than on single-deck and minibuses. For a 10 per cent increase in speeds total system costs are reduced by 18 per cent for double-decks as against 12 per cent and 7 per cent for the latter two respectively.

The model can also be used to show how the components of travel time vary with changed specification. As an example, Fig 2 shows how the average waiting times for passengers vary with the numbers of buses in use for Route 80 with the current demand level. The graph is similar to the system cost graph of Fig 1, as expected, since a large proportion of system costs are attributable to wait times. As argued in Section 5.1, wait times will decline with increasing numbers of vehicles. However, the rate of decline decreases and wait times become essentially constant after a certain number of vehicles are in use. (This is because doubling the number of buses in use would be required before the already low wait times are halved.)

Figure 3 shows how the average wait time varies with the demand rate for different numbers of single-deck buses. As might be expected, the average wait time increases with increasing demand. With the current number of buses (eight) on Route 80, a 50 per cent increase in demand generates a 60 per cent increase in wait times. Furthermore, the fewer the number of buses in use, the more sensitive is average wait time to demand level, over the range indicated. At the current demand level a 25 per cent reduction in the number of buses (from eight to six) presently used leads to a 40 per cent increase in wait times. With a 50 per cent increase in demand, the same reduction (25 per cent) in the number of buses presently used leads to an increase in wait times in excess of 100 per cent. Clearly a point is reached where the number of vehicles in use is inadequate to service the demand.

6. ROUTE CAPACITY

Output from the model has been used to establish the capacity of Route 80 for different vehicle types operated at different headways. For any 'run' of the model a steady state is reached during the two peak periods, when all buses are in use. The system is most likely to be working at, or near, capacity (in the sense of carrying most passengers) in one direction only — the peak direction of travel. Data are recorded of the numbers of passengers being handled by the system (i.e. the numbers able to board), their waiting times during the peak periods and in the peak direction. It is these data which have been used to determine the route capacity.

Figure 4 presents the way in which average wait times of passengers respond to changes in the numbers using the system during the peak, and in the peak direction, for minibuses. Each curve is for a different frequency of operation expressed as number of buses per hour. For any vehicle type (the analysis has also been done for double- and single-decks) curves representing a higher frequency lie to the right of curves representing a low-frequency operation.

The curves have been drawn to pass through those points on the *Y*-axis where wait time would be exactly equivalent to half the headway. If buses maintained strict headways and passengers arrive randomly, then this would be the expected wait time. In practice, bus headways are not constant, and thus passengers are not always able to board the first arriving bus, particularly as demand level increases. Consequently, there is quite a variation in the average waiting times.

For the most part the curves show common characteristics. Wait times are relatively insensitive to passenger throughput, up to a critical threshold in demand; beyond this level wait times become unstable and uncertain. The threshold of passenger throughput at which this transformation takes place may be regarded as the limit in the capacity of the route, beyond which wait times for passengers become unacceptably high and/or unreliable. This point is reached when the probability of being able to board the first arriving bus becomes small. If passengers are forced to wait for two or more buses before being able to board, large queues build up and the system quickly becomes overloaded.

Table III. Route 80 capacity data

Vehicle type	Vehicle passenger capacity (crush/normal)	Frequency (veh/h)	Limit of passenger throughput* (passengers/h)	Associated limiting wait times** (min.)
Double-deck	140/100	5.1	650-800	13-23
Single-deck	99/60	4.7	450-525	15-17
		5.1	550-650	15-25
		6.2	600-700	13-20
Minibus	48/30	7.3	300-400	8-23
		11.6	500-600	7-15
		16.0	800-900	10-20

* In peak period and peak direction

** These are the wait times which can be expected up to the limit of the passenger throughput; beyond this threshold, wait times become unstable

Table III summarises the capacity data for a number of different operating policies. A range is given for the limit of capacity (passenger throughput) because the threshold which is derived from graphs is not precise. The associated wait times are also given, which indicate the level of service which can be expected by users when the route is working at its limiting capacity.

Clearly, the data presented in Table III provide capacity information for a relatively small number of the many possible system options (combinations of vehicle type and frequency of operation on Route 80). It does show, however, how capacity and level of service could be tailored to meet the specific needs of a route. If the level of service (i.e. acceptable wait time) is fixed, and the peak demand level (in the peak direction) is known, then it should be possible to select a fleet option which meets this required specification. Indeed, it should be possible to extend Table III to cover many more options, and thus to provide a set of operating guidelines for bus operators. Whether or not such guidelines would be universal for all routes would need further examination. Route length may have some influence on capacity, particularly if passenger 'lead' (i.e. average passenger trip length) increases with route length. If this is the case, then capacity guidelines would have to be prepared for different route length and/or average passenger lead.

7. MODELLING OTHER ROUTES

Two other DTC routes (89 and 521) have been modelled, partly to check that the simulation is sufficiently robust to handle other conditions and partly to see whether results from one route are readily transferable to another. The performance of the three routes was compared, using the simulation model, by imposing on each, in turn, the same bus capacity, provided three different ways: using five double-decks, eight single-decks or 16 minibuses. Table IV shows the comparative performance of each bus type for the three routes. Taking each vehicle type in turn, it is evident that system costs increase broadly in line with average passenger lead (journey distance). This is true for each vehicle type. Minibuses provide the cheapest system cost (per passenger and per passenger-km) for the shortest lead (on Route 80), while single-deck buses provide the cheapest system costs for the longer leads found on Route 89 and 521. The rate of increase in system costs with increasing lead is fastest for minibuses: the 90 per cent increase in journey lead between Route 80 and Route 521 is associated with 79 per cent increase in system costs per passenger-km. The corresponding increase in system costs for double-decks is 41 per cent, though they do start at a higher level (Rs0.44 per passenger-km) than minibuses (Rs0.33 per passenger-km).

There is some evidence here, then, that the longer the average lead, the larger the vehicle should be. This analysis is far from exhaustive, however. In particular, demand level is likely to be a key component in such an analysis. Table IV represents the situation for an overall demand of about 8-10 000 passengers per day. Using the same capacity to meet a much lower demand is likely to be reflected in much less sensitivity in costs because user costs will not be so dominant. For a demand rate of half the current level on Route 80 there is very little difference in system cost for a wide range of numbers of any vehicle type. If the same holds true for longer journey leads (and this seems likely) then for lower demand levels the minibuses could equally well be used on long routes with long average leads. This proposition has not yet been tested.

Another point concerning Table IV is that the comparison is simply between vehicle types of equivalent capacity (i.e. the capacity of 16 minibuses, eight single-deckers and five double-deckers is approximately same). An operator may be more interested in knowing what is the best option (in the sense of providing a service at minimum system cost) given the constraint of an operating cost budget, i.e. it might be better to compare options in terms of those with equal operating cost. If the performance of the buses was compared on operating costs alone, it seems probable that minibuses would provide a much more expensive service in comparison with the other two types.

8. SUMMARY

The main criteria for comparison of route performance using the model is 'total system cost' which is made up of total bus operating costs plus total travel time costs. (The latter excludes walking costs which are deemed to be independent of the characteristics of a single route.)

Whatever the specification of the route and the vehicle in use, there is evidently a trade-off between increasing operating costs (of using more vehicles) and decreasing time costs (from the improved service level). For small numbers of vehicles the reduction in travel times outweighs increased operating costs, but a point is reached where additional vehicles add more to total system costs than is 'saved' in reduced travel times. Thus there is a minimum total system cost. Using the Route 80 input data, and comparing three vehicles sizes, minimum total system cost is achieved when employing 12 single-decks. This option gives a slightly lower total system cost than employing 14 minibuses with 30 seats, and a substantial saving over the use of 10 double-decks (these being the optimum numbers of vehicles of each type for the specified conditions).

It is apparent from the analysis that the value of time adopted is critical to the decision-making process. The larger the vehicles, the more important is the time component in

Table IV. Comparative performance of three bus types (of equivalent capacity) on three routes

	16 Minibuses			8 Single-deckers			5 Double-deckers		
	80	89	521	80	89	521	80	89	521
Average wait time (min.)	6.5	33.7	61.6	11.5	30.3	59.9	18.5	64.3	71.2
Average ride time (min.)	13.2	24.4	25.3	14.7	31.3	28.3	15.6	29.6	25.7
Average passenger lead (km)	5.4	8.5	10.3	5.3	10.0	10.5	3.5	9.9	10.0
System cost									
— per passenger (Rs)	1.78	4.18	6.04	1.88	4.16	5.67	2.32	5.48	6.17
— per passenger-km (Rs)	0.33	0.49	0.59	0.35	0.42	0.54	0.44	0.56	0.62
Operating cost									
— per passenger (Rs)	0.60	0.69	0.83	0.31	0.46	0.38	0.28	0.35	0.36
— per passenger-km (Rs)	0.11	0.08	0.08	0.06	0.05	0.04	0.05	0.04	0.04

total system costs. Thus the value of time and the travel-time weighting factor (the ratio of wait times to in-vehicle times) critically affect the total system cost; the higher these values, the less likely that larger buses would be favoured over small buses. The sensitivity analysis demonstrates this relationship.

Total system costs are much less sensitive to changes in unit operating costs of buses, because operating costs make up a relatively small proportion of the total.

As might be expected, the level of demand is also a critical factor in route performance. Total system costs rapidly escalate when the same number of vehicles is used to meet an increase in demand level. The sensitivity analysis of Route 80 suggested that this cost-escalation is much greater for the smaller and larger vehicles, in comparison with the single-deck buses.

Using the model, an attempt has been made to establish the capacity of Route 80 for different vehicle types at different headways. This is based on the level of passenger throughput (passenger per hour in the peak period and peak direction of travel) beyond which average passenger waiting times become unreliable and unstable. Only a relatively small number of possible options have been examined, but it is demonstrated that capacity and level of service could be tailored to meet any particular service needs.

When comparing the performance of different-size vehicles on different routes there is evidence that the longer the average lead (passenger journey distance), the larger the vehicle should be.

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The TRICS Consortium of South-East County Councils has released version 2.2 of its Trip Rate Data Base System. The new database contains some 1 340 days of travel data from 390 different sites, an increase of some 30 per cent on the previous version and largely due to the inclusion of data from Manchester and Lancashire, an increase of industrial estate data and the inclusion of a number of superstores in central London. According to Colin Eastman, an Associate of JMP Consultants who manage the system on behalf of the County Councils, 'although the size of the database is expanding rapidly we can still identify significant gaps in its coverage — we are particularly keen to hear from anyone who has access to data on B1 developments and data within London'. There are now 57 registered users of the TRICS System.

- JMP Consultants are to carry out for TRICS a two-month study to identify maximum parking demands for a wide range of land uses. Their research will examine the data currently held within the TRICS database and supplement these with data from extensive automatic traffic count data for a series of retail stores. This is the third research project to be commissioned by the TRICS Consortium. The first project on the temporal stability of trip rates has been concluded while the second project, which is a series of before-and-after studies of the introduction of retail stores, will be ongoing throughout 1991.

Editorial Index: Volume 31, 1990
Readers and Librarians are reminded that the Editorial Index to Volume 31, 1990, appears on pages 678 and 679 of this issue.