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MICROSCOPIC MODELLING OF TRAFFIC MANAGEMENT MEASURES FOR GUIDED BUS OPERATION

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Abstract

Guided bus systems are increasingly appreciated as a cost effective method of luring travellers from private to public transport. This paper describes the developments made to enhance a traffic microsimulation model in order to help design and evaluate guided bus schemes and the complex traffic management issues which such systems present. The model framework is illustrated through numerical experiments on simple artificial networks where traditional bus priority measures are performed and compared with a base case without any form of bus priority. Future research is planned to include tests on real networks with guided bus schemes actually being considered for real-life implementation.

INTRODUCTION

In the UK, many local authorities and bus operators are beginning to appreciate the potential of guided bus systems. These systems use a dedicated guideway to enable equipped buses to bypass other traffic at congestion points (Read et al., 1990; DoT, 1995). Guidance can be achieved by mechanical means, such as specially fitted guidewheels in a track, or by electronic sensors that respond to a "wire" embedded in the road. For modelling and traffic management purposes, however, a more useful distinction is the degree of segregation afforded from other traffic. In particular, we shall focus on the case of kerb guided bus systems (those based on the use of guidewheels), which operate both on segregated sections of "guideway" and un-segregated on the normal highway.

The guideway provides a physical barrier to prevent violation and illegal parking by private motorists (a common problem with bus lanes painted on the highway), and by steering the bus allows narrower lane widths than usual to be used. This latter issue is important when space is at a premium, for example when the only space for the guideway and passenger access is in the median of the highway. The main advantage relative to light rail systems is the lower total infrastructure cost. The segregated guideway may be provided at the kerb or in the median, but is only needed at location and direction in which congestion occurs. Sections of guideway can be installed piecemeal according to the timing and amount of funding available; also, the existing bus fleet may be adapted to operate on the guideway. These systems also afford greater penetration into residential areas than is possible by light rail, by the bus operating in unguided mode.

There have been a number of these schemes in operation around the world, notably in Adelaide, Essen, Ipswich and Leeds (Pope, 1992). Applications are being considered for the UK in Hull, Avon, Oxford, Chester, Edinburgh and a second site in Leeds. Experience shows that central to the success of such schemes is their design. "The...implications for a guided bus system therefore are that great care needs to be taken in the application...of design features in a wide variety of potential applications, to achieve the most cost-effective and efficient rapid transit system." (Tebb, 1993).

In spite of its great potential and a number of actual operations of guided bus schemes, this area has attracted very little research attention. The UK Transport Research Laboratory is currently carrying out a study on the impact of such systems on patronage. The study reported here, funded by the UK Engineering and Physical Science Research Council, is investigating the unique traffic management issues these schemes present, and aims to find the most effective way of integrating guided bus into the traffic management measures for an urban network. The main objectives of the research are to:

1. Review current UK best practice in guided bus design, building on contacts made with local authorities, bus operators and consultants;

2. Develop a range of alternative traffic management designs for guided bus in urban radial corridors, with particular regard to: the location and operation of the guideway; entry/exit control; conflicting turning movements; pedestrian access and bus service levels.

3. Assess these alternatives using a traffic microsimulation model, based on data from three test sites, and compare them with traditional bus priority measures such as reserved bus lane and bus signal priority. Impacts to be measured include: guided bus travel time; non-guided bus travel time; private vehicle journey times; queues; pollutant emissions and pedestrian delay.

This paper describes the developments made to enhance a traffic network microsimulation model in order to meet the third task above. The model is extended to explicitly incorporate public transport networks, including regular bus and guided bus services, guideways, bus lanes, bus stops, selective vehicle detection and responsive traffic control.

Many of the modelling issues that arise in representing a physically segregated guideway could apply equally to traditional bus lanes and bus signal priority measures. In particular, both guideways and bus lanes are usually only available for a portion of a route, and at other stages the buses must operate in mixed traffic, possibly traversing complex signalized intersections or roundabouts. Therefore, in later parts of the paper, where reference is specifically made to guided buses and gûideways, this could equally have referred to those bus measures more generally in terms of their (intended) degree of segregation, rather than the physical means used to implement them (e.g. guideway, lanes painted on highway).

It is worth noting, however, that it is well known that parking and lane-use violations occur frequently with bus lanes painted on the highway, whereas they occur much less frequently with physically segregated lanes. Such violations have important implications not only for traffic performance evaluation, but also for detection of buses so as to give signal priority to buses if selective-vehicle-detection is not available. It could therefore be argued that a realistic model of the bus lane, traditional bus priority approaches should include the possibility of such violations, whereas in the segregated lane it may not be necessary, and in this respect the test results given could be said to relate more specifically to segregated guided bus operations.

In the following sections, the paper first outlines the modelling issues required for representing the kerb guided bus systems and associated traffic management measures. It then introduces the base traffic simulation model and the model techniques developed to implement the issues identified. Finally the paper presents example results of applying the model to test networks, and discusses the plausibility of the model outputs and the impact of design features on several measures of effectiveness.

THE MODELLING ISSUES

In broad terms, any framework aimed at evaluating the potential interaction of traffic management measures with kerb guided bus systems and traditional bus priority measures, should incorporate a traffic simulation model and a driver route choice behaviour model. The traffic simulation model is required to represent the detailed design of the guided bus systems with vehicle lane-changing operation, interaction between vehicles (especially between guided bus and other traffic at the entry and exit of the guideway) and responsive traffic signal controls. The route choice model is the demand side of the problem and is required to analyse car-drivers' re-routing behaviour in response to any perceived reallocation of capacity in favour of the guided bus.

More specifically, the following areas were identified as the key requirements of the network to be modelled:

Network specification:

- a network, rather than an isolated link or junction, in order to examine the effect of signal priority measures on offsets and therefore neighbouring junctions;
- a variety of intersection types: priority, signalised and roundabouts, to be able to represent fully the traffic control measures which are often in place at the intersections;
- bus stops and bus laybys, which may be placed anywhere along a link in either nearside or offside lane; and

- reserved, but non-segregated, bus lanes for buses and guided buses operating un-segregated. The lane reservation may be in operation only at certain times of the day, on either the nearside or offside lane, and may also be set-back at either end. The model should ensure that other vehicles correctly use any set-back space.

Data requirements:
- bus and guided bus services in terms of service schedule, route, and stops for the boarding or alighting of passengers; and
- Passenger-volumes and the effect on bus dwell times.

Policies:
- selective vehicle detection which trigger a signal response;
- journey time prediction algorithms for forecasting the arrival of the guided bus at the stop-line from its detection;
- a variety of responsive signal control policies, such as extension of green, early termination of red, and use of "payback" to maintain offsets and green splits on subsequent stages;
- the guided buses moving in a segregated guideway, and interacting with other traffic on entering and leaving guideway;
- partial or absolute priority given to the guided bus at roundabouts, and at merges on leaving the segregated guideway; and
- feedback effect of changing the signals, reducing the physical highway space available or increasing public service frequency on private motorists' choice of route.

Output specification:
- journey times, delays and queues for guided bus, ordinary bus and non-bus trips; and
- pollutant emissions and fuel consumption;

The effect on mode choice was considered to be determined by some exogenous model, since it was felt that the effect on patronage of these alternative design details would not differ greatly between designs (other than through journey times). Comparatively, other factors such as the appearance or marketing of the system and the fare structure may have more effect on the bus patronage.

For these purposes, it was decided to enhance the traffic microsimulation and assignment model DRACULA (Liu et al., 1995). This model represents the movement of individual vehicles through a network using a one-second increment, discrete time simulation based on car-following, lane-changing and gap-acceptance rules. It combines a traffic microsimulation with the modelling of the day-to-day evolution of individual drivers' route choices, based on their experiences of congestion on previous days.

Although the ultimate aim of the research is to incorporate both the traffic simulation of guided bus systems and its effect on route choice, the paper here will describe the first (but main) stage of the work in which route choices are assumed fixed. The transition to the case of variable route choice will not be a great step for the project, since DRACULA already has such modelling capabilities. It does, however, introduce a greater number of unknowns, with regard to the parameters of drivers' learning and route choice process, and would therefore require some sensitivity testing. For this reason, these initial results are given based on fixed route choices.

THE BASE TRAFFIC SIMULATION MODEL

The traffic simulation model, based upon which the new developments for guided bus modelling is enhanced, is part of the DRACULA (Dynamic Route Assignment Combining User Learning and microsimulAtion) suite of models. It is a microscopic simulation of the movements of individual vehicles through a network. It is a time-based simulation where the states (speed and position) of vehicles are updated at a discrete time interval of one second.

Vehicles are individually represented, each having a set of individual characteristics:

- vehicle type (car, bus, guided-bus, taxi, goods vehicles);
- vehicle length;
- minimum safety distance the driver prefers to keep away from the vehicle in front;
- normal acceleration the driver uses in normal car following conditions;
- maximum acceleration the driver can use;
- maximum deceleration driver uses in emergency braking conditions;
- speed factor, a multiplier of the link's mean free-flow speed, which gives the driver's desired speed on that link;
- risk factor, a multiplier of the mean gap which gives the gap that driver regards as safe to take.

These characteristics are randomly sampled from a normally distributed representation of the type of vehicle, with means and coefficients of variation defined by the user. The characteristics for each vehicle are chosen at the start of each trip, but are fixed during the trip.

Vehicles follow pre-defined fixed routes through the network. The assignment is carried out externally before the simulation using either the day-to-day demand model of DRACULA or the equilibrium assignment model of SATURN (Van Vliet, 1995). Vehicles' movements in the network are determined from their desired movements, the traffic regulations on the road and interactions with neighbouring vehicles through a car-following model and a lane-changing model.

The car-following model tries to represent the response of a driver in a stream of traffic to the behaviour of the vehicle ahead. When a vehicle is the leading one and is not approaching an intersection, or the headway with the vehicle in front is larger than a pre-determined threshold, the vehicle accelerates freely in order to reach its desired speed. If, however, a vehicle has an headway smaller than a pre-defined threshold, the vehicle uses an appropriate deceleration similar to that proposed by Gipps (1981) to avoid collision. In between the above two extremes, a vehicle follows its preceding vehicle and reacts to the time and space headway differences.

The lane-changing model executes the following steps:

- checking the lane-changing types: mandatory lane-changing where the vehicle has to change lane in order to get into the correct lane for its next junction turning movement or to avoid an obstacle on the road. Optionally, a driver may want to change lane in order to gain speed by bypassing a slower moving vehicle. In the next section, there are examples of the need to change lane in order to get into or out of a reserved lane, or to reach a bus stop.
- Selecting target lane. For the optional type of lane changing, the target lane can only be that on the right (for UK driving rules).
- Gap acceptance. The acceptable gap depends on a number of factors: the lane-changing objective, traffic conditions, and a vehicle's position with respect to the point where it has to make the lane-changing move (for example the position of the obstacle or the stopline of the link).

The measures of effectiveness (MOE) from DRACULA traffic simulation includes: travel time, distance, average speed, fuel consumption and pollutant emissions. A typical output from the simulation reports these MOEs at a fixed frequency and at the end of the simulation, and averaged for each type of vehicle, for each route taken, for each link on the network and for the whole network. At the user's request, individual vehicles' link travel times and vehicle space-time trajectories can also be requested for further analysis. There is an on-line animation of the movements of individual vehicles through the network.

BUS AND GUIDED BUS MODELLING METHODOLOGY

This section describes how the modelling issues identified in Section 2 are implemented in the traffic model of DRACULA. One of the objectives of the project is to compare guided bus operation with traditional bus priority measures, such as reserved bus lane and bus signal priority. This section also describes the development made in DRACULA to represent these traditional bus priority measures.

Public transport service

The guided bus and ordinary bus service in the model are described by:

- service number;
- vehicle type (bus or guided bus);
- service frequency (veh/hr);
- a fixed route in terms of nodes through the network;
- a list of bus stops en route.

Only the departure time of the service (via a fixed hourly service frequency) is modelled. The bus schedule (in terms of route timing points) is not represented in the current version.

Guided bus and guideway

Guided buses are represented in the model as a distinct type of vehicle. The distinction is made both in terms of vehicle characteristics and the traffic regulations governing their movement on the streets.

The guideway is represented as separate links, which can only be entered at the start of the link and exited at the end, unlike reserved lanes (see below).

Reserved bus lane

The lane reservation in the model is specified by:

- the link identification;
- location on the link (near or offside lane);
- type(s) of vehicles reserved for the lane;
- "set backs" at the beginning and end of the link;
- starting and finishing time of the reservation, measured from the start of the simulation.

The operational distinction between a guideway and a reserved lane which this implementation incorporates is that a bus may join the guideway only at dedicated points on the route whilst a bus may "drift" into and out of a reserved lane anywhere along its extent. A lane can be specified as reserved for one particular type of vehicle or a combination of vehicle types.

It is assumed that all bus drivers have perfect knowledge of the network. Thus they know if there is a reserved bus lane in the next link well in advance, and will try to move into a lane (in the current link) which leads it naturally (geometrically) into the reserved lane in the next link. If it is not possible to get into the correct lane in the current link, a bus will enter the next link and then keep looking for opportunities to move into the reserved lane.

In contrast, private vehicle drivers are assumed to have information about their next link only when they approach the junction. If the start of the reserved lane (in the next link) is further than a certain distance from the entry of the link, the drivers are assumed to be unaware of the reservation ahead. They would get into a lane in the next link according to their positions in the current link and the traffic situation in the next link. On the other hand, if the reservation started nearer to the entry of the link, the drivers would choose a lane other than the reserved lane and merge with other traffic if necessary.

Bus stop and bus layby

An ordinary bus-stop is a single sign on the road side and buses stop alongside the sign on the road for boarding or alighting passengers, thereby blocking upstream traffic in that lane. A bus layby, however, provides a space for the bus to pull into the bus stop and thus allows following traffic to pass. A bus layby in the model is represented as a special type of bus stop.

A bus stop is described by the following data:

- bus stop identification;
- the link it is on;
- location of the bus stop on the link, measured from the entry of the link;
- type of the bus stop (a bus stop or a bus layby);
- length of the stop (in case of bus layby);
- lateral location on the link (near or offside); and
- average passenger arrival rate at the bus-stop.

Before entering a link with a bus stop, a bus will try to get into a lane than leads to the lane with the bus stop. Failing to do so, the bus would first get into the next link then look for gaps to move to the lane with the bus stop. The bus would only try to get into a lane that permits its next junction turning *after* it has passed the last bus stop on the link.

The use of bus laybys on a guideway will enable off-line boarding to be represented, where local stopping buses do not impede the journey of express buses.

The passenger volume at each bus stop is drawn from a normal distribution with a mean representing the average passenger flow to the bus stop and a variance fixed for all bus stops. The bus dwell time at a bus stop is then related to the number of passenger (N) waiting at the bus stop as: ($a*N + b$) seconds. Here a is the time it takes for one passenger to get on a bus (including paying to get a ticket) and b the time for the bus' door being opened and closed. A value of a=4 second/passenger, and b=5 second as suggested by Clark and Pretty (1992) are used in the model.

Selective vehicle detection

Virtual detectors are placed on the road as a line across a lane. If the front bumper of a vehicle is upstream of a detector at time (t_0-dt) and it is at or has just passed the detector (regardless whether the rear-end of the vehicle has or has not passed the detector) at the following time step (t_0), a vehicle detection at time t_0 is triggered. With such a definition, a vehicle sitting on the detector does not trigger a detection.

The input data for a selective vehicle detector consists of:

- detector identification;
- the lane where the detector is placed;
- location of the detector from the stopline; and
- type(s) of vehicles to detect.

Journey time prediction

The time it takes for a vehicle to reach the stopline from its point of detection is modelled in three parts:

- time from the detector to the back of the queue, assuming free flow;
- time waiting in the queue; and
- time travelling to the stopline.

The ability to detect buses on the guideway will enable downstream signal operation to give buses an undelayed or less-delayed exit from the guideway.

Bus signal priority

When a bus is detected at time t_0 and predicted to arrive at the stopline at time t_a, one of two actions may be performed:

Extension, which extends the bus green period in order to allow the bus to exit; or
Recall, which terminates the bus red stage earlier in order to reduce the bus waiting time.

Figure 1 shows schematically the signal priority in a space-time diagram. The signals for the bus link are shown on the top, with $t_{\_r}$ and $t_{\_ra}$ representing the start and end time of the red aspect. $t_{\_ext}=t_{\_r}+E_{\_max}$, where $E_{\_max}$ is a user specified maximum allowed extension time. The distance from the detector to the stopline is d. Three bus trajectories from the detector to the stopline are drawn in dashed lines.

If a bus is predicted to arrive at the stopline just after the start of the red signal (case B in Figure 1), the bus green aspect will be extended by just enough time to allow the bus to exit. The amount extended depends on the predicted bus arrival time, subject to a user-defined maximum ($E_{\_max}$) and to minimum greens for the subsequent stages affected.

If a bus is predicted to arrive during the red, but an extension is not appropriate (i.e. requires more than the maximum permitted extension, case C above), then the duration of the bus red aspect may be reduced by a constant amount of 5 seconds. The length of other stages remains unchanged, so the length of the current cycle is decreased temporarily.

In other situation (case A in Fig. 1) the signals will not be changed.

Only one signal change (extension or recall) is permitted per cycle and stage extension or recall responds to the first bus detected. In all cases, the intergreens must be maintained for safety reasons.

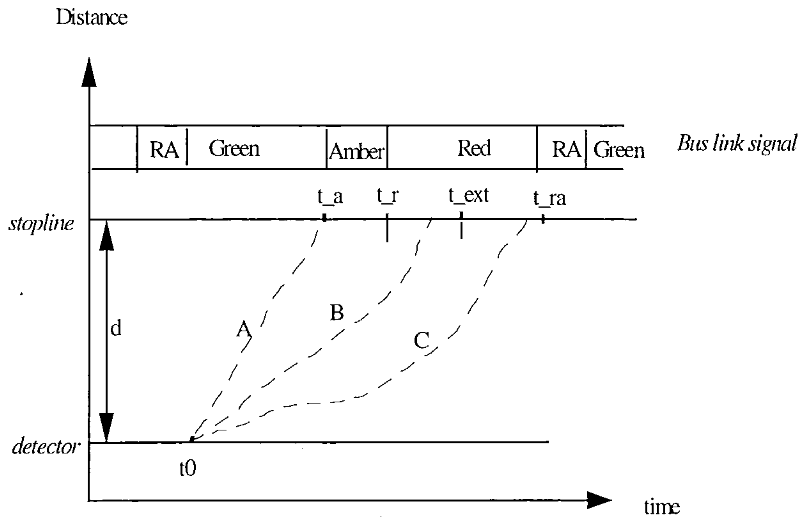

Figure 1 - Space-time representation of bus signal priority

If an extension (to the bus link green aspect) is triggered, the following stage will be shortened so that it will terminate at its normal time in the cycle. In the following cycle, the extension time is removed from the bus link green aspect and given back to the following stage. In the case of an early recall, the bus green terminates at its normal time in the cycle. In the following cycle the start of the bus green is delayed by the amount of recall time. This procedure is named *payback.* It is designed to maintain signal offsets and the long-term degree of saturation on all approaching links.

After an extension or recall in one cycle and a payback in the following cycle, there will be a recovery period of a given number of cycles during which no change in stage timing is permitted. This period is named the *cooling-off period* and is intended to let the system settle down. The number of cooling-off cycles is a user-specified parameter.

SIMULATION EXPERIMENTS

In this section experiments are conducted on artificial networks to simulate reserved bus lanes, bus stops, bus laybys, and a bus signal priority policy. The primary concerns of these experiments are to evaluate the versatility and effectiveness of the methodologies implemented in the above section.

Reserved lane

Figure 2 shows the topology of the test network. The total length of the arterial route is 600 metres; the reservation is placed on the nearside lane of the middle link which is 300 metre. The nearside lane of the middle link is for left and straight ahead turning movements and the offside lane for straight ahead and right turning movements. There are 17 buses per hour travelling on the arterial, 800 cars/hour from the arterial entry (zone 1) and 150 cars/hour from the north entry (zone 2). The lane is reserved from the beginning of the middle link to point B. Point S indicates a bus-stop which is used in the test in the next sub-section.

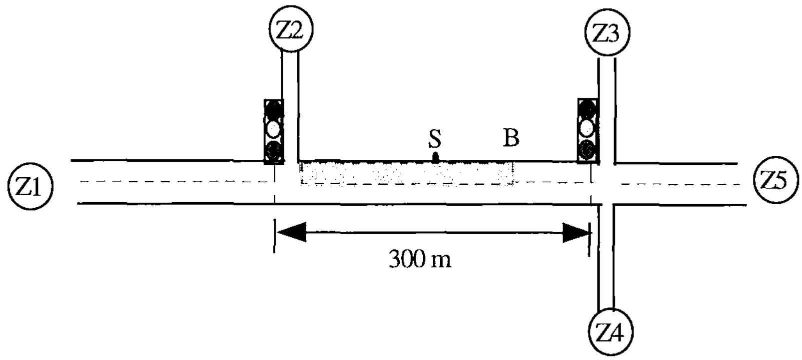

Figure 2 - The test network

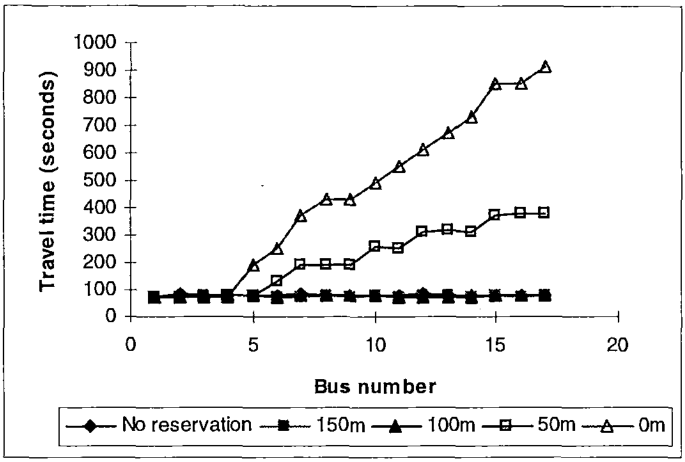

Figure 3a - Individual bus travel time in the five cases.

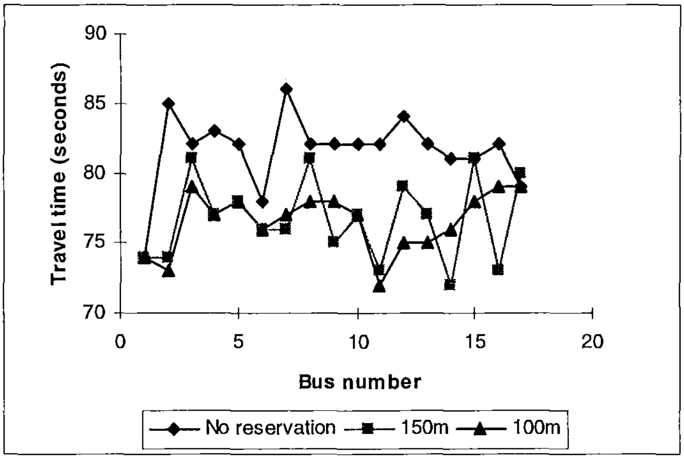

Figure 3b - An enlargement of Figure 3a with the first three cases.

Three cases of reservation are tested. The reservations all start from the beginning of the link but end with setbacks of 150, 100 and 50 metres respectively. The network performances, in terms of bus and car journey time, are compared with both the "base case" where there is no reserved bus lane and the case of full reservation where the lane is reserved from the entry to the stopline of the link.

An one hour simulation is conducted, with the simulation extended to allow all the trips to finish their journeys. In the cases of a reserved lane, the reservation is in action for only the first hour of the simulation. The car and bus travel times are recorded for each case and are shown in Figure 3.

Figure 3 shows the individual bus travel time in the network under all five situations. The values in the legend indicate the setbacks of the reservation. It shows that the bus journey times increase dramatically in cases of full reservation and with small downstream set-back. This is because the reservation reduces the link capacity for cars and the congestion on the link extends back to the entry of the link where the buses were caught up in the congestion.

With appropriate design of bus lane, a bus journey time reduction can be achieved. Here, implementing a set-back of 100 meters from the stopline, the average bus journey time is reduced from 81.3 seconds to 76.7 seconds over the 600-metre long arterial, a reduction of 5.5%. This is accomplished at the expense of an increase in car journey time of 5.0%.

Bus stops and bus laybys

The same test network shown in Fig. 2 is used here to test the performance of the bus stop versus bus layby. The stop is placed at 120m from the entry of the middle link (point S in Figure 2). An average of 120 passengers per hour arrive at the stop. There is no reserved bus lane.

Figure 4 shows the individual bus journey times for the two cases. It shows that in the case of a bus-stop, the journey times over the 17 buses tested is fairly uniform, with an average travel time of 82.5 seconds over the 600 metre arterial route. In the case of the bus layby, however, there can be seen a large fluctuation in bus journey times. Although the average is 95.1 seconds here, a mere 3% increase, there were four buses whose travel times were as high as 140 seconds. This is caused by congestion on the link with the buses in the bus layby having to wait longer to leave the bus layby.

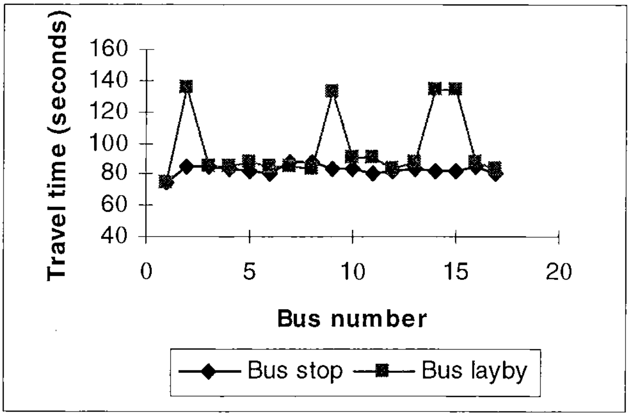

Figure 4 - Individual bus journey time in the presence of a bus-stop or a bus-layby.

With off-line boarding on the guideway this will not, however, be an issue since vehicle flows will be low on the guideway. So there is an expectation in a benefit with using bus laybys instead of bus stops on the guideways.

There was not much benefit to the car traffic when a bus-stop became a bus-layby; the average car travel time reduced from 81.2 seconds to 80.5 seconds, a reduction of less than 1%.

Bus signal priority

To test the effect of this form of bus priority a simple two junction network was constructed. Each link in the network is 200 metres long. A two junction network was chosen in preference to an isolated junction network so that the benefit of payback in maintaining junction offsets could be incorporated into the experiment. Both junctions are equipped with selective vehicle detectors 100m from the stoplines. The signals at each junction run two stages with a 60-second cycle time. The maximum extension period is 5 seconds. The early recall period is fixed at 5 seconds. The generated headway for buses is 90 seconds giving a volume of 39 buses in the demand period of 1 hour. Private traffic is dominant in the same direction as the bus route, with the total volume of traffic being 1600 vehicles during the demand period.

Table 1 - Bus and Car journey times

	Bus travel time(seconds)			Car travel time(seconds)		
NSEED	Base	Test	% diff.	Base	Test	% diff.
800	330	270	-18.1%	253	226	-10.6%
1800	323	293	-9.2%	250	231	-7.6%
50000	338	321	-5.0%	255	245	-3.9%
6890	343	286	-16.6%	255	243	-4.7%
100	335	327	-2.2%	246	245	-0.4%
Mean	334	299	-10.4%	252	238	-5.5%
Stdv	7	23		3	8	

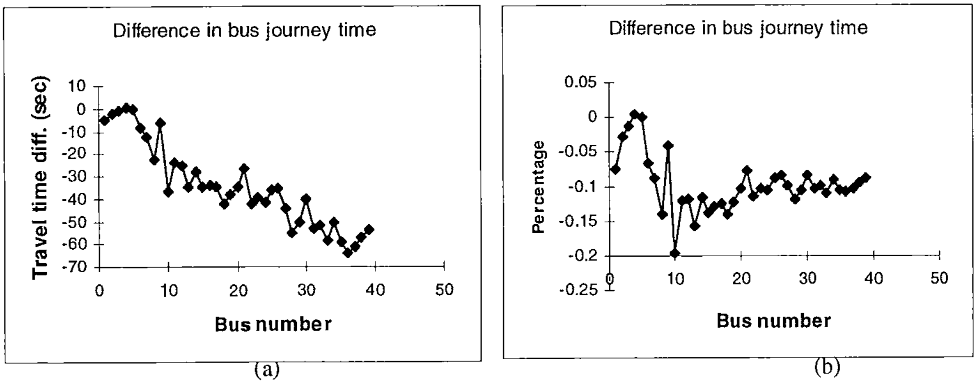

Figure 5 - Difference in individual bus travel time with and without signal priority, in terms of absolute difference (a) and percentage difference (b).

The base case is to run the simulation, for a 60 minute simulation period, without any form of bus priority. The test case is to enable both extensions and recalls in one direction at both of the junctions, with a "cooling-off" period of 2 cycles (120 seconds). In both cases five simulations were conducted, each with a different random number seed. The vehicle-averaged results are shown in Table 1.

The differences in individual bus travel time between the averaged test cases and the base case are plotted in Figure 5. In the base case the journey time for buses tends to increase for late departures, as they would encounter more congestion. With selective vehicle detection, the bus journey times also increase as late departure times, but generally less so than in the base case. Only 14 out of the 195 journeys simulated showed an increase in journey times over the base case, with an average reduction being approximate 10.3% of the journey time (maximum reduction of 37%) and a maximum increase of 7%. The journey time for private vehicles has also decreased by 5.5%.

Of note is the fact that some buses actually take longer to complete a journey when bus priority is activated. This is to be expected since the payback mechanism is not guaranteed to restore the traffic state to that which would be the case without priority. Thus the traffic state may temporarily become more congested, therefore delaying both cars and buses. A delayed bus may be unable to reach a stopline at a suitable point in the extension or recall "window" thereby suffering further delay. It is, however, clear that on the whole, selective bus detection and extension and recall actions reduce bus journey times.

CONCLUSION

This paper describes the methodology developed for modelling and evaluation of traffic management measures for guided bus systems. The development is made under the general framework of the DRACULA microscopic traffic simulation model. Guided bus services are represented by service frequency and a fixed route with bus stops at specified points en route for alighting passengers. Two types of bus stops are represented: ordinary bus stop and bus layby. Bus dwell time is represented and is related to the passenger arrivals at the bus stop, and, in case of bus laybys, to the traffic flow on the road when the guided bus operates in mixed traffic condition. Sections of guideway are represented as separate links on the road network where the buses can only enter at the start of the link and exit at the end. Also represented is the traditional reserved bus lane with setbacks at either end of the link. Here a bus may drift into and out of a reserved lane anywhere along its length.

Simulation experiments show that a reserved lane with appropriate setbacks could be very effective for achieving bus journey time reduction and that relative performance of a bus stop verses bus layby depends largely on the traffic flow on the link. A bus stopped at a bus layby does not impede traffic flow but may find itself having to wait longer to leave the bus layby when there is congestion on the road. This may not be an issue for guideway since vehicle flow is expected to be low on them. So a benefit with using bus laybys instead of bus stops on the guideway is to be expected.

Algorithms for selective vehicle detection and journey time prediction are developed. Two bus signal priority measures are represented: the signal responds to the detection and prediction of bus arrival time at the stopline; it may extend the bus green period to allow the bus to exit, or terminate the bus red aspect early to reduce bus waiting time. A payback and cooling-off mechanism is introduced to maintain signal offsets and the long-term degree of saturation on all approaches. The simulation experiments show clearly that selective bus detection with the bus signal extension or recall reduces bus journey time, and that the percentage bus journey time reduction reaches a stable level after initial variation.

In general the results show that the model responds logically to changes in model inputs, the model is flexible and provides a useful environment for testing alternative bus priority designs and traffic management strategies prior to field experiment.

Research is now in progress to apply the model to larger, real networks and to investigate guided bus schemes actually being considered for real-life implementation. A range of alternative traffic management designs for guided bus systems in three urban networks will be developed and assessed. The assessment will be based on a wider range of measures of effectiveness, including only not travel time and queuing delays, but also environmental and safety measures.

A further step in the research is to incorporate both traffic simulation of the guided bus systems and their effect on drivers' route choice using the full day-to-day assignment and simulation framework of DRACULA. A greater input is required from empirical research on drivers learning and route choice behaviour.

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