BUS PRIORITY PLANNING IN ADELAIDE

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ABSTRACT: *A review is made of some features which can be used to improve the capacity of the urban road transport system, particularly during peak periods, to carry larger volumes of people, with only small capital investments. The review considers work done in Adelaide on ways of improving bus operations in that city. Features which are expected to reduce the length and variance of bus travel times, such as traffic signal modifications and reserved lanes are described and discussed.*

1. INTRODUCTION[(1)*]

In large cities today we usually find one common feature - much of their road transport system is pressed to its limits for several peak hours each day, and on occasions they may experience high levels of congestion during other parts of the day. Underlying this congestion is the provision of a limited quantity of resources for the purpose of moving goods and people. It is through an effort to utilise efficiently these limited resources that the concept of priority for certain vehicles, and in particular buses, arises.

The first part of this paper discusses briefly the nature of the urban road passenger transport system. The latter part examines some forms of priority for certain vehicles, and describes some of the bus priority measures being investigated by the S.A. Department of Transport in the Adelaide metropolitan area.

As the most severe congestion occurs on the roads during the two daily peak periods, priority under these conditions of peak loading are of predominant concern. However, many of the measures to be discussed can be applied during the remainder of the day, due consideration being given to the varying nature of traffic during the day.

2. URBAN ROAD PASSENGER TRANSPORT

The urban road transport system is defined as consisting of two basic components:

(a) the transport infrastructure

(b) the vehicles which use this infrastructure.

For a given infrastructure and mix of vehicles, there is a fixed vehicle capacity for the road. Given a limit on the quantity of resources available, particularly in the public sector, the principal aim of transport engineers should be to increase the efficiency with which those resources currently available are used. One of the ways of achieving this is to introduce low cost features that will enable the existing resources to carry the maximum demand flow of people with minimum average delay to them. This aim must be tempered to some extent by the need for the roads and vehicles to carry goods, serve adjoining properties and fulfil other functions.

While the vehicle capacity of a road can be improved somewhat by a change in the mix of vehicles, and the person-carrying capacity raised further by an increase in vehicle occupancies, perhaps the greatest potential for an increase in the capacity of the road to carry people arises from a change in the mode of travel to buses.

This potential improvement in the capacity of a road is limited at the current time by a number of factors. Buses by nature of their size and operation differ significantly from other vehicles on the road. Many of these differences such as the need to stop at the kerb at frequent intervals and the difference in manoeuvrability place them in a position of disadvantage relative to other vehicles. As noted by the Commonwealth Bureau of Roads,[(2)]

*References follow the text, commencing on Page 14.

'On inner urban arterials, other traffic causes delays to buses producing significantly lower speeds and increased bus operating costs'. Travel times not only increase, but become less reliable. This detracts further from the quality of bus travel, inducing people to travel by car, which in turn aggravates the problem even more.

The acceptance of bus travel as a means of increasing the person capacity of a road also brings with it benefits such as reduced fuel and other resource consumption.

3. LOW COST TRANSPORT IMPROVEMENTS

Mindful of the need to seek low cost transport improvements, and of the problems faced by buses in providing an adequate level of service (in particular, a fast and reliable service), the S.A. Department of Transport has in recent years studied bus operations in Adelaide. The aim of these studies have been threefold:

(a) To locate areas where buses experience delays and/or difficulties;

(b) To develop solutions in these cases, and to seek their installation; and

(c) To make detailed assessments of these improvements to evaluate their effectiveness.

The last aim is felt to be particularly important given the difficulty of theoretically evaluating the potential benefits of many of the proposed improvements.

The Department began its work by considering improvements at individual locations where problems were apparent. Last year however, studies of two routes(3) were undertaken to investigate, using the experience gained from the smaller surveys, what measures of bus priority could be undertaken on a larger scale. The two trunk route studies undertaken were aimed at producing proposals for bus priority which could be implemented as demonstration projects with the double purpose of demonstrating to the public the operation of bus priority, and secondly, to provide the opportunity of measuring the impace of such priority.

Generally, the improvements considered can be classified into two categories:

(a) Passive stragegies

(b) Active strategies.

These descriptions are used to indicate the likely perceived effect of the proposed changes on road users other than those in buses or other priority vehicles.

3.1 PASSIVE STRATEGIES

The passive strategies generally encompass those changes that aim to improve the level of service for existing bus passengers and to attract additional passengers without affecting other modes. Utilised in this approach of "improvement by persuasion" are improvements in features such as the fare structure, fare collection system, bus design and marketing. Such improvements should decrease bus travel time, make simpler and more comfortable the process of travelling, and improve the general public's perception of the attributes of bus travel.

Studies of bus boarding and alighting times in Europe(4), (5), (6) would, despite the variability in their results, indicate that by utilising the most suitable fare structure, fare collection system and aspects of bus design, bus boarding times should be able to be reduced significantly. In Adelaide it is estimated that the use of dual boarding lanes, one lane for those who would cancel their pre-purchased tickets themselves and the other for those purchasing tickets from the driver might reduce morning peak period boarding times by possibly up to two seconds per passenger. With dual lanes, alighting times might be reduced by possibly one second. These figures are particularly significant in the central city area where kerb space for bus stops is at a minimum and the time saved could improve the throughput of buses.

The study by the Bureau of Transport Economics in Perth, "Consumer Preferences in Urban Buses and Bus Services",(7) provides useful insights into possible transit improvements.

Any improvements made under this category of passive strategies must be adequately relayed to the non-bus-travelling public. Otherwise there is little chance of the changes having an impact beyond those people already using the bus, with, correspondingly, no change to the mode split and the person capacity of the road. Even with this advertising, it can be expected that the shift to bus travel induced by the passive strategy will be limited as it relies on the willingness of people to change their perceptions and beliefs on the nature of bus travel. The degree of the shift is also limited in that even with the improvements proposed, the bus system cannot match completely the positive attributes of the car, making the private benefits of travelling by car still greater than the private benefits arising from bus travel. Finally, the passive strategies overcome only some of the features of road management which decrease the attractiveness of bus travel. They have little impact on the relationship between bus and other traffic movement on urban roads, an aspect which has a significant impact on the total length and variability of bus journey times.

3.2 ACTIVE STRATEGIES

Active strategies are considered necessary principally because of the limitations of the passive strategies in achieving the desired aim of increasing the person-carrying capacity of the road. The active strategy seeks to redistribute the available road space such that the occupants of high occupancy vehicles, and buses in particular, are able to utilise more fully the potential passenger-carrying efficiency of these vehicles.

It is in the area of active strategies that the term "bus priority" is used. This term is generally loosely applied and interpreted. While it describes the situation where buses are given priority over other vehicles, it gives no indication as to whether this priority can be justified on grounds of equity, or if it is an arbitrary allocation of rights to buses. In this paper it will be generally used to describe the former (i.e. on grounds of equity). If desired as a matter of policy, buses can be given additional priority in order to improve further their attractiveness and use.

Active strategies incorporate a number of features including changes in traffic engineering practice and the provision of reserve lanes of various types. Some of these are described below, with some of their characteristics being commented on.(8)

Traffic Signals

(a) General Approach

One of the active strategies which best illustrates the concept of priority on a basis of passenger-carrying efficiency is one which requires a fundamental change in the current approach to traffic engineering. Current traffic engineering practice is based frequently on an analysis of vehicle delays, vehicle capacities and so on, the aim being to maximise vehicle (or equivalent passenger car unit) flow, and to minimise the average vehicle delay. The substitution of 'people' for 'vehicle' should provide equity for all vehicle occupants and a more efficient allocation of the current transport resources.

The effect of such a change is that traffic signals would for instance have their phase lengths altered to reflect the principle of minimising average person delays at intersections. A change of this nature could be expected to increase the capacity of intersections significantly. While the change may increase delays for some above current levels, it does in fact give recognition to the desired travel paths of individuals in the metropolitan area.

Little work appears to have been done on the topic of changing the method of traffic signal analysis as described above. In studies done for the S.A. Department of Transport, the cycle time determined by the method described in the ARRB Bulletin No. 4(9) has been used, and the pahse lengths within that time varied. De Leuw et al, in a study of Payneham Road(10) suggested that at one intersection the green time for the major arterial road would increase by 20%. Pak-Poy et al, in a study of the North East Road(11) considered that such a change would have a much smaller impact, in the region of 5 or 10%. Obviously, further analysis of this proposal is required.

This proposal, despite its advantages in increasing the person-carrying capacity of an intersection does have limitations. Buses with their large passenger volumes mainly justify the additional green time for the road on which they travel. This additional time however, can be used by low occupancy vehicles, limiting the potential increase in the person capacity of the intersection. Such an increase in the volume of other vehicles could have the effect of delaying buses further, and of limiting their capacity to utilise the additional green time effectively.

Further, the change is only truly equitable when those 'efficient' vehicles which justify the additional green time are present at each phase to utilise it. For instance, when a bus does not approach during each green phase, fixed time lights will induce a distortion in the equitable nature of the system. In these circumstances there will be an inducement for artificial growth on the main road of low occupancy vehicles, in much the same way as the current approach induces growth on cross roads.

(b) Low Volume Intersections

At intersections where buses approach at a rate of less than one per signal cycle, an alternative approach is to set the signal phase lengths to reflect minimum person delay without the influence of buses. Buses and the intersection would then be fitted with equipment that would enable the signals to be pre-empted as a bus approached. Should a bus approach when the signals were green, the phase would be held for a specified length of time to allow the bus to reach and cross the intersection. If the signals were red, the green phase for the cross road would be foreshortened to its minimum length, and the green phase given to the bus as soon as possible. A limit would be placed on the number of successive extensions of a single green phase.

While in the strictest sense this priority should apply to reasonably full buses only, a case might be made for empty buses on-route to also have priority in order to maintain a high level of regularity in bus journey times.

In their report on North East Road, Pak-Poy et al[12] propose that a system utilising buried induction loops set about 50 metres back from the intersection stop line and on-bus transponders be used at several intersections. While bus volumes are low at some of these intersections, they are as high as 50 buses/hour at others. The system has been proposed for the latter as an alternative to modifying the traffic signal timing. The transponders could also be fitted to emergency vehicles for use in cases of emergency.

(c) Traffic Signal Co-ordination

Recently a study aimed at formulating traffic management proposals to improve bus operations in and about the retail core of the City of Adelaide was undertaken by Pak-Poy et al. In their report[13] they recommended that the use of the computer program TRANSYT[14] be considered in the development of traffic signal timing plans for the City's co-ordinated traffic signal system. This program enables buses to be given some measure of priority within systems of co-ordinated traffic signals without appreciably disbenefiting other traffic.

Reserved Lanes

The active strategy that general road users will most readily perceive as having an effect on them is the reservation of road space for particular vehicles. This strategy is necessary to overcome the limitations of the strategies mentioned previously, and to ensure that significant benefits accrue to the occupants of those vehicles to which priority is given.

The reservation of lanes on major roads for use by particular vehicles is generally a new phenomenon for the current generation of people in Australia. Trams have always to an extent forged for themselves a space of road. Sydney in recent years has operated a transit lane on the main arterial route between Balgowlah and Cremorne on the north shore, and has recently installed similar features at other locations. However, there would not at the current time appear to be widespread and systematic acceptance of reserved lanes in Australia.

The warrants for introducing reserved lanes can include the minimisation of person delay, equity in the distribution of road space, or an attempt to increase the potential passenger-carrying capacity of the road.

At a symposium held in Britain in 1972, Allen[15] listed several criteria for the assessment of the feasibility of bus lane schemes in London. Some of these are as follows:

(a) It should give a significant advantage to buses;

(b) It should not seriously reduce traffic capacity or cause secondary congestion by developing excessive queues;

(c) It should give a net benefit to the community and should have a reasonable cost/benefit ratio;

(d) It should be reasonably easy to enforce; and

(e) The frequency and occupancy of buses should be high enough to encourage compliance by other drivers.

In discussing the reservation of road space, three aspects in particular need to be defined:

(a) the road space to be reserved

(b) the vehicles permitted to use the lane

(c) the time during which the reserved lane is to operate.

Principally, there are two types of reserved lanes, one on the approach to an intersection, and the other in the mid-block section. The former of these can either be carried through to the intersection stop line or be terminated at a predetermined point prior to the intersection. The latter generally extends through most of the mid-block section, and can be combined with either of the above lanes on the approach to an intersection. Vehicles permitted to use the lanes could consist of either buses, high occupancy vehicles, high density vehicles, commercial vehicles, emergency vehicles, or any combination of these. The lane could operate either during peak hours, 24 hours, or a figure in between. Huddart[16] notes that the first two periods are more common, with 12 hour periods being an undesirable option. The period chosen will depend on features such as the nature of the reserved lane, the street loading requirements of adjacent properties, the period of major congestion and levels of policing required. Generally it would appear that the most common period of operation is during the peak period in the peak direction. To ensure a high level of acceptance by other road users, this period should generally be uniform over all the metropolitan area. In instances where there is a need for say 24-hour operation, special signing and perhaps more substantial indication of the reserved lane is necessary to achieve adherence.

(a) Reserved Lane on Intersection Approach

A reserved lane on the approach to an intersection is suitable if sufficient intersection capacity is available, and a predominant desire is to maximise time savings with a minimum length of reserved lane. The lane should in this case extend back from the intersection stop line to a point which will enable the priority vehicles access to the lane at all times.

These reserved lanes are usually situated by the kerb and it is therefore desirable to permit all left-turning vehicles use of the lane. To ensure that the lane is free enough to permit buses to effectively use the lane it is desirable to limit the availability of the lane to vehicles about to turn left and buses only. Other vehicles such as pedal cycles and possibly motor cycles could be considered.

The principal limitation of a bus lane on the approach of an intersection is that it can reduce the vehicle capacity of the intersection. Allowing the left-turning vehicles to use the lane can be expected to limit this negative impact.

Several lanes of this form have been installed in Adelaide. They have been installed as early, low-key bus priority measures with no supporting legislation. One example is on Peacock Road as it approaches Greenhill Road from the City through the South Parklands (see Fig. 1, page 8). The approach on Peacock Road has been widened by one lane at the intersection stop line by reducing the size of the island used to channel the free left-turn traffic. After parking ceases in the kerbside lane of Peacock Road (some 180 metres back from the junction), buses and left-turn vehicles share the lane, with buses being able to gain access to the intersection stop line on most occasions.

A complete 'before and after' survey was not conducted at this intersection because it was considered that there might have been a high violation rate of the lane because of the lack of legislation. There has in fact been a high level of acceptance of the lane, with only a small number of other vehicles using the lane at the intersection stop line. While no complete survey was made, a preliminary investigation into the proposal(17) indicated that the average saving per bus might be 67 seconds. This produces a significant benefit, given that in this situation other vehicles are not disadvantaged by the lane.

A second location where some action has been taken to aid bus movement is in King William Street in the Adelaide city area. While a reserved lane has not been declared as such, all kerbside parking has been banned on the western side of the street from Franklin Street to North Terrace between 4.00 and 6.00 p.m. during the week. However, because bus volumes are high, (an average of 213 buses during the two hour period) traffic wishing to travel straight through intersections in the kerbside lane run the risk of being caught behind a bus. This leaves essentially only left-turning vehicles and buses in the lane.

A study of this scheme,(18) has indicated that there was a very small improvement in bus travel times during the period of the parking ban. It has also been perceived by observers that the traffic flow appears to be smoother and more orderly.

(b) Reserved Lane with Set-Back

To overcome the problem of a reduction in the vehicle capacity of an intersection resulting from the continuation of the reserved lane through to the intersection stop line, the lane can be terminated at a point some distance back from the intersection. This enables all vehicles to use the available lanes at the intersection. Further, it reduces the volume of buses required to generate a net overall benefit for road users. With a set-back of optimum length and a high level of intersection saturation, a bus lane can be justified for bus flows of 'probably less than one every two or three minutes'.(19)

The lane is usually reserved for the exclusive use of buses, though low density and vulnerable vehicles such as bicycles and motor cycles might be permitted to use the lane as well.

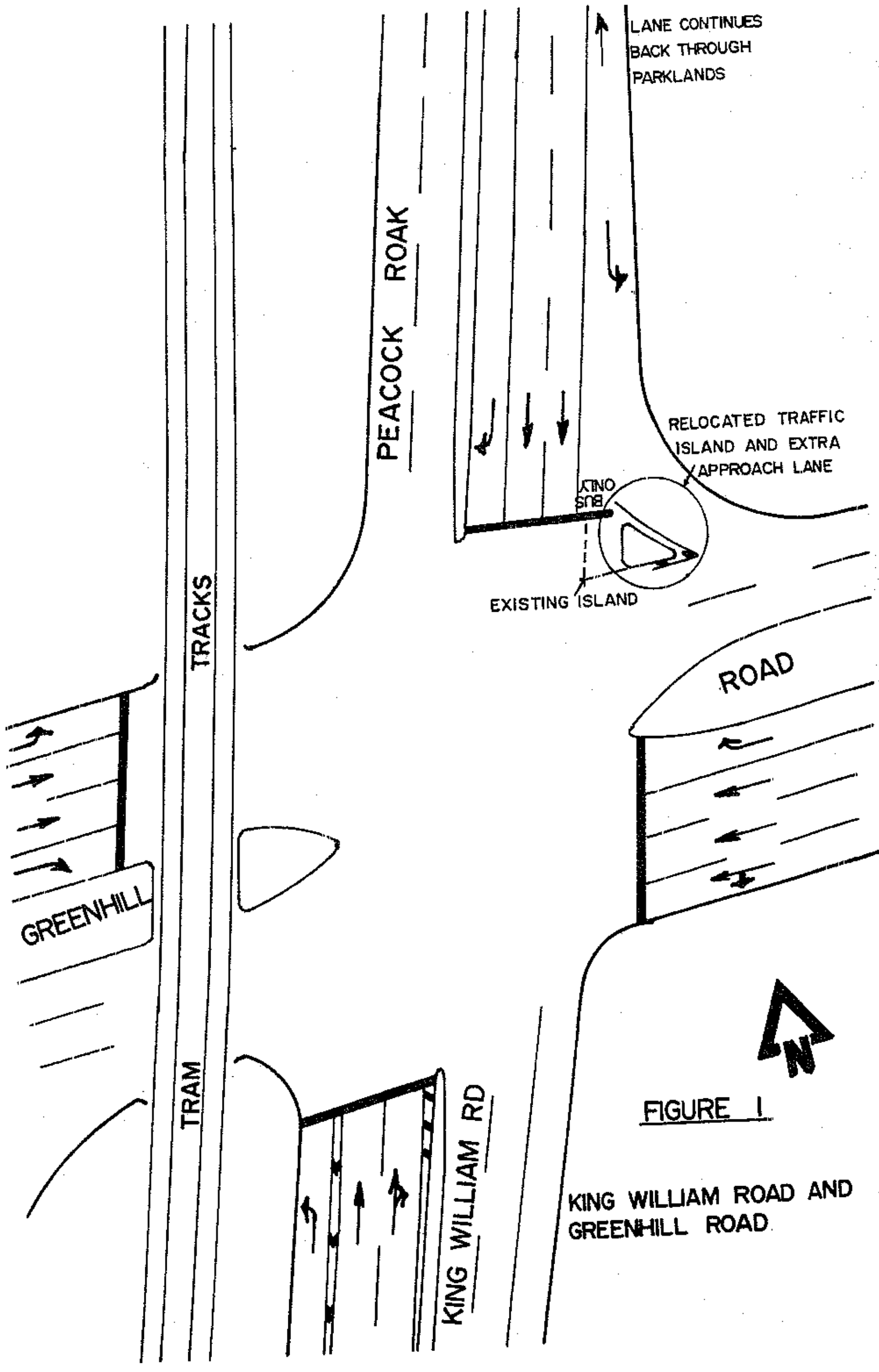


FIGURE 1

KING WILLIAM ROAD AND GREENHILL ROAD

The S.A. Department of Transport is currently investigating the possible installation of a number of reserved lanes of this form at other locations in Adelaide. In most instances the reserved lanes are newly created lanes, either the product of road widening or of the division of an existing approach of two lanes into three. One of these locations is the Maid and Magpie Corner at the junction of Payneham, Magill and Fullarton Roads and North Terrace. It has been suggested (20) that a kerbside bus-only lane be introduced on the city-bound carriageway of Payneham Road, operating for approximately 40 buses/hour in the peak between points approximately 300 and 60 metres prior to the intersection (see Fig. 2, page 10). The benefit/ cost ratio for this proposal, taking into account the possible need to re-sheet the road prior to re-marking the lanes, is estimated to be 3.3. This scheme is currently being given detailed consideration.

(c) Mid-Block Reserved Lanes

(i) Kerbside with-flow

While the substantial benefits from reserved lanes accrue from locating them on the approaches to intersections, further benefits may arise by continuing the reserved lanes through the mid-block section. This extended lane, which would begin either at or soon after the previous intersection, could be combined on the approach to intersections with either of the lanes proposed previously.

The beginning of the lane at a regular distance soon after the previous intersection, should decrease the uncertainty experienced by drivers of other vehicles as to where the priority lane begins. The continuous lane also creates a more substantial feature which is likely to gain the attention of road users, make more obvious any infringements, and affect the mode split. It also provides protection for priority vehicles should congestion occur in the mid-block section, and eliminates the need for vehicles to sort themselves out as they approach short reserved lanes at successive intersections. Finally, the operation of buses in a separate lane to the bulk of the traffic may offer advantages to traffic, given that some of their delays may be due to buses.

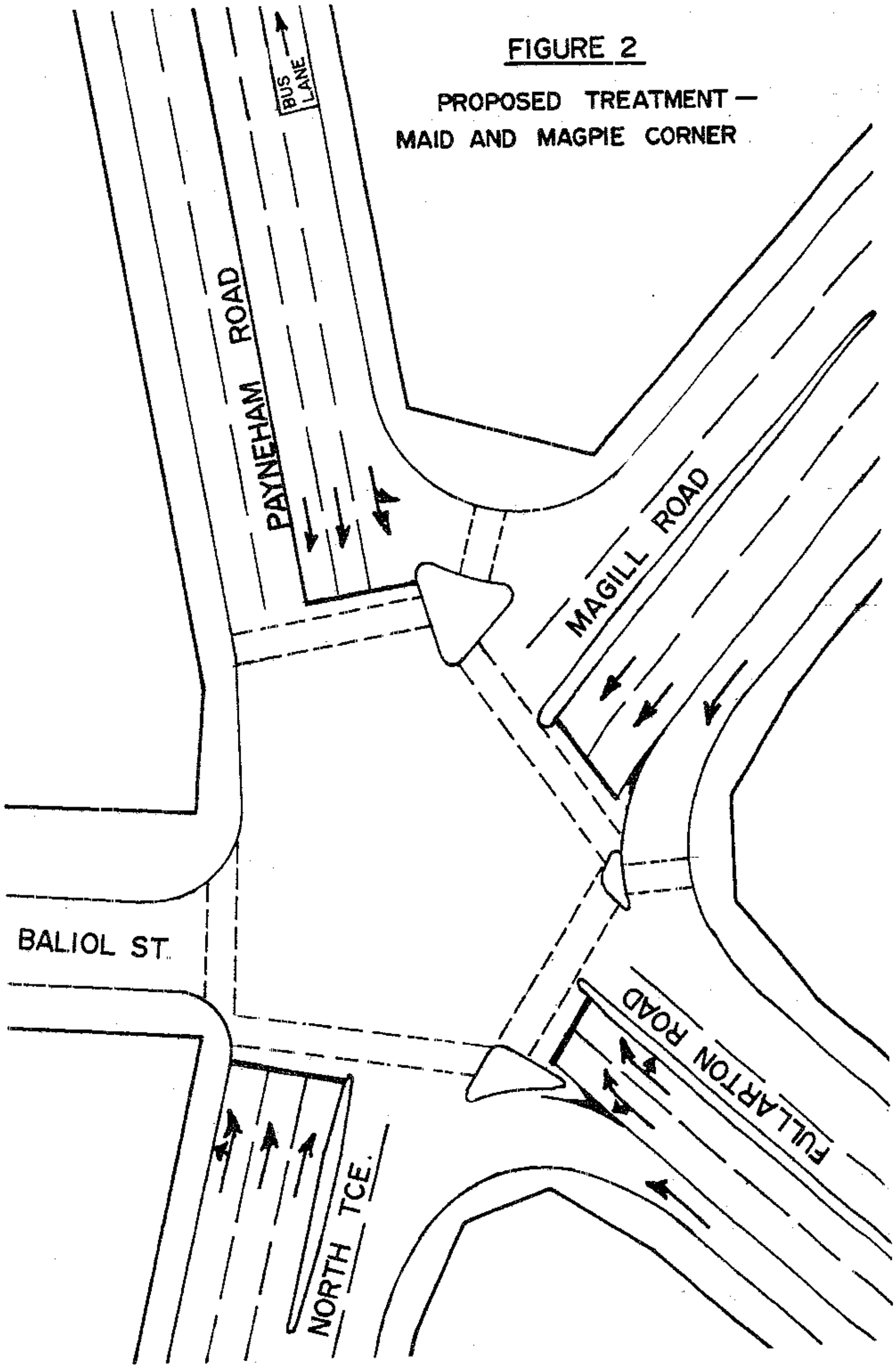
Because of the less severe congestion in the mid-block section of a road, it may be possible to permit other vehicles such as high occupancy cars and taxis to use the reserved lane without detracting from the level of bus service in the mid-block section. Note should be taken however, that the addition of these extra vehicles may impose inequitable delays on bus passengers at intersections.

In reviewing the possible vehicular content of the lane, consideration should also be given to the volume of buses using the route. It is suggested that (21) where buses must stop in the kerbside lane for bus stops, difficulties may be encountered when bus flows exceed 120 buses/hour. If bus bays are available for use, this volume can be increased to 600 buses/hour.

It is proposed that these mid-block reserved lanes generally operate in a similar fashion to clearways; that is, during the peak period in the peak direction. This ensures that properties adjacent to the road have reasonable access to the kerbside lane for loading purposes. In some locations it may be both desirable and feasible

FIGURE 2

PROPOSED TREATMENT — MAID AND MAGPIE CORNER



for the lanes to operate 24 hours each day.

In their study of the City to Tea Tree Plaza bus route, Pak-Poy et al(22) have suggested that reserved lanes should be installed along some of the route for the use of buses, bicycles, motor cycles and emergency vehicles. To cater for left-turning vehicles and to overcome to some extent the problem of gaps occurring between buses, left-turning vehicles would be permitted to use the lane as long as they turned left at or before the next junction on the left or the end of the bus-only lane. It should be noted that these vehicles would not be restricted to this lane, so that for instance an express bus could utilise an adjacent traffic lane to pass a local stopping service as required.

Generally the proposed bus-only lanes have been terminated prior to signalised intersections in order to maintain the vehicle capacity of the intersection and to minimise the delays to other vehicles. In some locations the lane has been carried through the intersection, either because of some traffic management detail, because there appears to be sufficient intersection vehicle capacity, or to enable surveys to be made of the relative impace of these measures.

This proposal provides buses, whose volumes along the route range from 10 to 120 buses/hour in the peak period with much freer operating conditions. Currently along most of the route are two traffic lanes and a parking lane in each direction with no clearway provisions. It has been suggested that where buses carry one-third or more of the person-flow along the road, a widened kerb lane be reserved in the peak period in the peak direction for the use of the vehicles described above. A preliminary survey indicates that bus passengers account for a third or more of the person-flow along the inner 10.7 kilometres of the route. At the City end of the route buses carry some 75% of the person flow.

It is expected that this proposal, which is currently being studied in detail by the S.A. Department of Transport should have minimal impact on other road users in the mid-block section, and may benefit them in several ways. These include the fact that left-turning vehicles can use sections of the kerbside lane which is currently used for parking, and there will be fewer buses in the general traffic lanes. It is also expected that it will be easier to police these bus-only lanes than transit lanes, as it will only be necessary to identify non-priority vehicles travelling in the reserved lane across a junction with a road on the left.

It is difficult to quantify the overall changes in travel time that may result from the installation of this bus lane, but it can be expected that the occupants of vehicles permitted to use the bus lane will achieve lower and more regular travel times. The travel times for occupants of vehicles outside the lane might go up or down. This will depend on, amongst other things, the effect of removing some vehicles from the general traffic lane and the degree to which the bus lane creates a vehicle capacity restraint on the roadway.

To provide data on the impact of bus priority, it has been proposed that a complete 'before and after' survey be conducted on the above bus priority demonstration project. Features to be measured could include travel times and the volume and occupancy of all vehicles, this data being related to the lane on the road. Bus timetable adherence, intersection delays, accident rates and opinion surveys would also be made.

A general guide to possible bus passenger travel time savings that may arise from the introduction of reserved lanes can be gained from the experience of other cities. The data available is however an average figure, and represents time savings from a wide range of facilities operating in varying traffic conditions. The average time savings for all the bus lanes installed in London (some 32 km.) is about two minutes per kilometre.[23] On the 6.4 km. transit lane between Balgowlah and Cremorne via Spit Bridge in Sydney, the mean bus travel time decreased by 11.2 minutes (46%), and the standard deviation of bus travel times by 78% to 1.8 minutes.[24] Of particular significance in these figures is the remarkable improvement in the reliability of running times.

De Leuw et al,[25] in their study on Payneham Road in Adelaide, suggested that travel times for buses might be reduced by three minutes along the three kilometre route with the introduction of a transit lane.

(ii) Contra-flow

The use of contra-flow reserved lanes is generally restricted for safety reasons to buses, can operate either by the kerb or in the centre of the road, and should operate 24 hours per day. They can be used in one-way street systems where it is required that buses should travel against the grain in order to save a large detour. They can also be used in situations where it is not possible to provide a with-flow kerbside bus-only lane in each direction of traffic flow, and an alternative is to provide one additional lane in the centre of the road which can be used by buses travelling in the peak direction only. The main problem encountered with the latter proposal is that bus passengers must enter and alight in the centre of the road, a potentially dangerous situation in a city unused to such occurrences, such as Adelaide.

Depending on the location, such lanes appear to be justified for quite small flows of traffic, possibly only four buses/hour for a low cost contra-flow lane in a one-way street system.[26]

4. CONCLUSIONS

Given a limit in the quantity of resources available, both natural and financial, there is a need to seek ways of using more efficiently those transport resources currently available. This requires a fundamental change in the approach of traffic engineering, and an acceptance by all, including road users, that one of the principal aims of the transport system, particularly during peak periods, is to move as many people as possible with minimum total delay.

While buses appear to have the potential to achieve such an aim, they are at the current time subjected to large and variable delays from traffic congestion, limiting their effectiveness. The South Australian Department of Transport has undertaken a number of studies to develop and evaluate schemes which will enable buses to provide a much higher level of service for their patrons.

These studies have indicated that a wide range of features can be used to overcome the deficiencies of the current transport system and to increase its ability to carry satisfactorily much larger volumes of people with only small capital investment. Reserved lanes, for use principally by buses, appear to offer particularly substantial benefits, by improving the current level of bus service, protecting the level of service from further deterioration in the future, and, with a shift in the current mode split, an increase in the person-carrying capacity of the road.

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(1) The author is grateful for the assistance given by people in the S.A. Department of Transport in the preparation of this paper. However, final responsibility for the views expressed remains with the author.

(2) COMMONWEALTH BUREAU OF ROADS. (1975). *Report on Roads - 1975.* (Commonwealth Bureau of Roads: Melbourne.) p.127.

(3) These two studies were as follows:

(a) Payneham Road - from Fullarton Road to O.G. Road (3 km.). See also (10).

(b) City of Adelaide to Tea Tree Plaza via North East Road (14 km.). See also (11).

(4) WATTS, P.F. (1974). *Passenger Handling Performance of One-Man Buses - TRRL Supplementary Report 114UC.* (Transport and Road Research Laboratory: Crowthorne.)

(5) CUNDILL, M.A. & WATTS, P.F. (1973). *Bus Boarding and Alighting Times - TRRL Report LR 521.* (Transport and Road Research Laboratory: Crowthorne.)

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(8) For a more detailed analysis of bus priority systems and further references, see

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(10) DE LEUW, CATHER OF AUSTRALIA PTY. LTD. & R J. NAIRN AND PARTNERS PTY. LTD. (1976). *A study of Alternative Bus Priority Improvements on Payneham Road.* (South Australian Department of Transport: Adelaide.) p.25.

(11) P.G. PAK-POY & ASSOCIATES PTY. LTD. (1976). *Bus Priority Demonstration Project: Adelaide to Tea Tree Plaza.* (South Australian Department of Transport: Adelaide.) p.p.24, 25.

(12) ibid. pp. 35, 63, 72-75.

(13) P.G. PAK-POY & ASSOCIATES PTY. LTD. (1976). *Traffic Management Improvements for Buses Around the Retail Core of Adelaide.* (South Australian Department of Transport: Adelaide.) p.9.

(14) The following report has further details on this system:

ROBERTSON, D.I. & VINCENT, R.A. (1975). *Bus Priority in a Network of Fixed-Time Signals. TRRL Report LR 666.* (Transport and Road Research Laboratory: Crowthorne.)

(15) ALLEN, B.L. (1972). *Bus Priority Measures in London. TRRL Report LR 570.* (Transport and Road Research Laboratory: Crowthorne.) p.22.

(16) HUDDART, K.W. (1976). Bus Lanes - their problems and advantages. *The Highway Engineer.* 6(7), p.22.

(17) P.G. PAK-POY & ASSOCIATES PTY. LTD (1975). *Adelaide Bus Operations Study 1974.* (South Australian Department of Transport: Adelaide.) p.52.

(18) P.G. PAK-POY & ASSOCIATES PTY. LTD. (1976). *King William Street Bus Lane - Before and After Survey.* (South Australian Department of Transport: Adelaide.)

(19) NATO COMMITTEE ON THE CHALLENGES TO MODERN SOCIETY. (1976). op. cit. p.21.

For details of research on the length of the set back, see

(a) COBURN, T.M. & COOPER, B.R. (1973). *Bus Priority Experiment on the Test Track. Proceedings of the Symposium on Bus Priority held at TRRL, 1972. TRRL Report LR 570.* (Transport and Road Research Laboratory: Crowthorne.)

(b) BLY, P.H. (1973). *Use of Computer Simulation to Examine the Working of a Bus Lane. TRRL Report LR 609.* (Transport and Road Research Laboratory: Crowthorne.)

(20) P.G. PAK-POY & ASSOCIATES PTY. LTD. (1976). *Traffic Management Improvements for Buses at the Maid and Magpie Intersection.* (South Australian Department of Transport: Adelaide.) pp.11, 12.

(21) NATO COMMITTEE ON THE CHALLENGES TO MODERN SOCIETY. (1976). op. cit. pp.16, 54.

These references do not make completely clear whether the bus capacities given are for freeways or for urban arterial roads. It is suggested that the figure of 600 buses/hour applies to freeways, and 120 buses/hour possibly to urban arterial roads.

(22) P.G. PAK-POY & ASSOCIATES PTY. LTD. (1976). *Bus Priority Demonstration Project: Adelaide to Tea Tree Plaza.* op. cit. pp.53, 54, 65.

(23) HUDDART, K.W. (1976). op. cit. p.21.

(24) NEW SOUTH WALES DEPARTMENT OF MOTOR TRANSPORT. (1976). *Evaluation of Transit Lanes.* (N.S.W. Department of Motor Transport: Sydney.) p.14.

(25) DE LEUW, CATHER OF AUSTRALIA PTY. LTD. & R.J. NAIRN AND PARTNERS PTY. LTD. (1976). op. cit. p.88.

(26) NATO COMMITTEE ON THE CHALLENGES TO MODERN SOCIETY. (1976). op. cit. p.46.