Towards a National Guideline for Bus Priority Measures

Grant Gordon, Senior Roading Engineer, Opus International Consultants Ltd

Grant is a traffic / transportation consultant with over 20 year's experience, principally in road design and investigations. For 11 years he has been with Opus, the last 8 in the Auckland office, providing technical oversight to the design of highway alignments, intersection improvements, bus, cycle and pedestrian facilities. Grant is an experienced Road Safety Auditor.

Abstract

Increasing demand to improving the attractiveness of public transport alternatives and the reliability of achieving their timetables is leading to increased provision of bus priority facilities. The focus of the Land Transport Management Act (LTMA) on public transport alternatives is improving opportunities for the development of these facilities.

However, there has been little guidance developed in New Zealand on how to provide for buses, resulting in variations in approach between Road Controlling Authorities (RCA's), and some safety issues developing. This paper reviews the growing provision of bus priority facilities, and some of the problems encountered from a designer/safety auditor perspective, with a view to providing guidance on some key areas, and improving safety of operation. This paper also reviews the New Zealand experience to date, so may not cover some bus advance facilities developed overseas, but not yet in use here.

In focussing on facilities to improve bus operation, this paper does not extend to cover many general issues associated with bus routes on public streets, such as conflicts between traffic calming measures and bus operation.

Forms of Bus Priority Used In New Zealand

Bus priority treatments in New Zealand have generally been based on features developed overseas. These include the following features.

<u>Bus Lanes</u>

These are parts of the carriageway width that are reserved for the use of buses, plus motorcycles and bicycles unless signs exclude them (refer Road User Rule). In certain circumstances they may be used by other road users.

However, in some instances it is desirable to be more restrictive on the use of bus lanes, reserving the lane exclusively for buses to avoid safety or operational issues. Examples include bus advances at signals, motorway bus shoulder lanes, or narrow kerbside lanes in urban streets. In these instances more restrictive control on use needs to be imposed and communicated to road users.

In some instances High Occupancy Vehicles (HOV's) may be permitted to use reserved lanes. These are often referred to as Transit Lanes, and allow typically cars and light vehicles carrying a defined number of occupants to use the lane along with buses and cycles.

An example is Onewa Road in North Shore City, which has a morning peak Transit Lane accommodating vehicles with three or more passengers. Large preceding signs clearly identify permitted users (buses, motorcycles, vehicles with at least three occupants).

Bus Bypasses
These are shorter sections of bus lane, designed to give buses the opportunity to advance more quickly past a localised constraint, such as an intersection control.

Bus boarders
These are kerb build-outs that allow buses to stop without pulling out of the kerbside lane, to minimise the delay rejoining the traffic stream, or to reduce illegal parking on bus stops.

Bus Advances
These allow buses to go to the start of a queue at traffic signal controlled junctions. The system uses a preceding set of signals to hold general traffic while buses in a kerbside bus lane proceed to the second signals. This is most useful where buses have to execute right turns requiring them to weave across lanes from a kerbside bus lane. The buses are able to weave or turn in advance of the general traffic phase.

Traffic Signal Bus Pre-emption
Traffic signals can be fitted with a facility to bring forward or extend a green phase when a bus is detected approaching the intersection.

Dedicated Busways
These are bus facilities physically separated from the surrounding road network, but linked at key points to allow access for permitted vehicles.

Currently the North Shore has the only example in New Zealand under construction, with one station and associated park and ride carpark already in operation. Stage 1 of the facility is anticipated to become operational next year, providing a separated bus route about 7km long between Akoranga Station (near Esmonde Road) and Constellation Station, with another two intermediate stations. The busway is intended primarily to accommodate buses, with the number of HOV's permitted to use the route being controlled to maintain smooth operation.

Bus Stations and Transport Interchanges
These facilities provide for transfers between transport modes or between bus routes. Examples include:
Busway Station – These can range from simple stations on busways to larger interchanges where passengers on feeder routes transfer to mainline

services, and may include kiss and ride or park and ride carparks, cycle parks, toilets and ticket sales. The proposed North Shore Busway's Akoranga Station is such an example, featuring a kiss and ride carpark. Other stations further out at Constellation and Albany feature larger Park and Ride Carparks.

Bus / Rail / Ferry Interchange – The existing Britomart Station, with buses on street, rail below ground, and ferry terminal across Quay Street

Problems and Solutions (Guidelines)

This paper divides the issues facing designers of bus priority facilities into three separate types of facility, as these have slightly different operating environments. The three categories are:

Separated busways and stations
Motorway facilities
Local Road facilities

Separated busways and stations

Currently there are no pure busways operating in New Zealand, although the North Shore Busway is currently under construction and due to open in 2007. Thus no New Zealand operational experience is available.

In terms of guidance, a busway design manual was developed for the North Shore Busway, based largely on Canadian experience. This manual appears to offer a good starting point for the development of dedicated busways.

Further there have been Safety Audits carried out on the busway proposals, which have been undertaken by auditors with overseas experience of such facilities (e.g. Australia, Canada). Some observations arising from these sources are as follows.

Bus driver eye height can vary, with newer low floor buses having driver eye height in the vicinity of 1.8m. While this is a significant improvement on the car driver eye height of 1.05m, bus deceleration can still govern vertical alignment design, as the bus deceleration rate is less. The Design Manual for the North Shore Busway project recommends limiting bus deceleration to $1.5m/s^2$ for the comfort of standing passengers.

Busway speeds should be aimed at minimising delays for buses, to make them as competitive with private cars as practical. However, motorway speeds cannot be sustained through on line stations. Generally stations should be designed for typical urban speeds (50km/h posted limit, 60km/h design speed).

The ideal solution is to have off line stations with buses diverging from the busway to access intermediate stations, and merging into the busway again after. However, this requires stations to be well spaced, and significantly increases the required corridor width.

As with sight distance criteria, vertical and horizontal design should be tailored to maintaining the comfort (and safety) of standing passengers. All curves should be provided with suitable spiral transitions to avoid sudden changes in centripetal force.

Cross sectional width should allow for opposing buses to pass each other comfortably. Austroads Rural Road Design and SHGDM give good guidance on required cross sectional elements. However, there are further considerations.

Provision of continuous shoulders is often impractical, so as a minimum provision should be made for buses to pass broken down vehicles, albeit by crossing the centreline. A broken down bus will pull across to the left, but will not park much closer than a metre from a barrier, to allow passengers to alight and transfer to a replacement bus. Thus the absolute minimum cross sectional width between barriers should be 1m + 2.5m + 1m + 2.5m + 1m = 8m. However, on higher speed routes consideration should be given to providing sufficient width to allow restricted two way operation past a stopped bus. Further, where barriers or fences are used either to control access to busways or because provision of clearzones is difficult, shy line distances should be applied as per SHGDM. The North Shore Busway Design Manual recommends a minimum of 10.6m width between barriers.

Barriers should be strong enough to redirect errant buses, requiring a TL-4 desin standard or higher. Furthermore, consideration should be given to the consequences of taller buses rolling as they are redirected. Thus bridge abutments or piers should be at least 900mm behind the face of a rigid barrier.

Checks should be made to ensure that headlight glare between busways and parallel roads is suitably screened.

At stations care needs to be taken with the design to ensure that buses do not cross the centreline when pulling out. Ideally a barrier should be provided in the median to prevent pedestrians crossing between platforms except at designated and controlled or grade separated locations.

Through stations, particularly on line ones, there is a conflict between avoiding a wide appearance to control speeds and the need to allow some separation between through vehicles and buses stopped or about to pull out. Speeds through stations can be reduced by gateway type features on approaches, and combinations of horizontal curvature and vertical elements to interrupt visual leads into or through stations.

Bus stopping positions should be assigned on platforms to minimise the risk of buses not being able to pull up to the platform and clear the through busway. This also reduces the risk of passengers not being able to flag down their bus from a platoon of buses. In Auckland platoons of five or more buses are common in the commuter peaks. A distance of seven metres from the back of one bus to the front of the following was found to be needed at North Shore Busway platforms, to allow buses to pull out around each other without crossing the centreline. Bus tracking should be checked with a suitable design programme.

Busway intersections should be located clear of station platforms to provide correct sight distances around buses stopped to pick up passengers.

Care needs to be taken with the choice of design vehicle, as trends are towards larger, higher capacity buses. Currently six wheeler coaches up to 12.8m long, and with low floors are becoming commonplace in Auckland. There has even been consideration of single unit buses up to 14m long. Such vehicles have long front and rear overhangs. Currently operating 3 axle designs can have front and rear overhangs exceeding 2m.

The front corner of buses pulling into platforms can track up to several hundred millimetres beyond the kerb face, and on leaving the tail corner of a bus pulling out sharply can track over half a metre behind the kerb face. This poses a considerable safety risk to pedestrians on the platforms, so a yellow line should be marked with tactile surfacing on the platform, at least half a metre behind the kerb, with a suitable message such as keep behind yellow line.

Access to busways from the local road network should be designed to ensure that only buses proceed onto the busway stations, with other vehicles clearly directed away. Ideally service vehicles (such as for supplying refreshment vending machines or carrying out maintenance and repairs at stations) should be accommodated well clear of station platforms, and ideally should not impinge on bus operations.

Where HOV's are permitted on busways, care needs to be exercised to ensure that the regulation of HOV's onto the busway does not interfere with bus access to the station.

Motorways

Bus facilities are provided on some Auckland motorways, often on emergency stopping shoulders, which have been widened to allow buses to operate on them in peak flow periods. The shoulder still accommodates emergency stopping (such as puncture or mechanical failure) and emergency services or enforcement activity. Ideally some additional widening should be provided so that enforcement does not disrupt bus operation.

However other vehicles, including motorcycles, are not permitted to use the shoulder as a lane. This can cause confusion as bus lanes on the surrounding local street networks can accommodate motorbikes. A possible solution may be to include symbolic signs prohibiting motorcycles.

Motorway bus lanes are becoming increasingly prevalent in Auckland, where buses are affected by congestion, often over considerable distances (greater than 5km).

Currently Transit has developed some guidelines on installation of motorway bus shoulder lanes within the Auckland Region, with a bus symbolic sign, written into the supporting bus lane bylaw. Ideally one standard of bus symbol should be adopted for all bus lanes.

Lanes are not continuous across motorway ramps and at local shoulder narrowing (such as bridges). Bus operation on motorway shoulders terminates before on and off ramps, to avoid conflicts between buses and traffic entering or exiting the motorway.

Bus shoulders also need to terminate before localised shoulder narrowing. Opportunity for overruns should be provided as with general traffic merges (lane drops, passing lane ends, motorway entrances).

The asphalt surfacing layer on many Auckland motorways is not continuous across the shoulder, but ends about 0.5 to 1m beyond the edgeline. This is usually not a significant issue for traffic, but can be a problem for buses as their wheels may track in this area. The problem is most significant where the lip created at the edge of the surfacing exceeds 25mm, and can cause the buses to roll uncomfortably for standing passengers. Ideally the shoulder in the vicinity of wheel tracks should be free of any longitudinal lip.

Buses will not track within about 500mm of gantries, walls, and barriers, especially if the highway curves. Higher bus speeds (above 50km/h) also increase the amount drivers shy away from barriers. Therefore the lane width should not be reduced below 3.0m, with a further 1m minimum clearance to guardrails, giving a minimum distance from the general traffic lanes of 4.0m.

A bus lane end should be located to ensure good visibility. Avoid ending lanes over or beyond crests. This applies to lanes on local roads as well.

Ideally the sight distance to markings should allow comfortable bus deceleration to typical traffic speeds, plus a merge length at the reduced motorway operating speed. However, a check should be made of sight distance required if buses and general traffic are operating at speeds of say 10km/h less than the posted speed limit. This is suggested as occasionally buses may use shoulder lanes to undertake traffic that is operating at only slightly reduced speeds.

Bus shoulder lanes are intended to be used during peak flow periods, when speeds of both motorway traffic and the adjacent bus shoulder lane are constrained by congested conditions. However, there is currently no control on operating speeds in bus shoulder lanes, and significant speed differentials can arise. These can be quite intimidating to drivers, especially where widths are constrained.

One possible solution may be to limit speeds within bus shoulder lanes using VMS, with the variable speed limit based on a maximum 20km/h speed differential from traffic in the adjacent general traffic lane. General motorway traffic speeds can be monitored by detector loops, and the whole process automated.

Another possibility is to limit bus use of the shoulder to periods when congestion imposes significant delay to them. This is currently done on southbound lane 1 of the northern motorway under Shelly Beach Road. Then when the bus shoulder is operating, a suitable fixed limit could be chosen, say 50km/h.

Currently enforcement appears to be by intermittent Police patrols. Suitable space should be allowed for police enforcement activity, otherwise patrols risk obstructing the facility they are seeking to protect. Some overseas sources recommend enforcement areas be 4m wide, to maintain clearance from buses, with suitable stacking length and tapers either end.

Avoid ending bus shoulder lanes adjacent to motorway lane drops or motorway entrances, as this effectively merges three lanes into one, at one point. Drivers in general traffic lanes will be preoccupied with the motorway merge, and may not consider the needs of buses attempting to merge into their lane from the left.

Where bus shoulder lanes are provided on ramps, care needs to be taken at signal controls, to ensure that buses can operate safely alongside general traffic lanes that may be congested or operating at substantially lower speeds. This includes ensuring that signal controls clearly indicate when buses are being given priority while other traffic is being restricted.

Street lighting should be checked to ensure that an adequate level of illumination is achieved over shoulder lanes.

Urban Streets

On urban streets few authorities have developed formal guidance. Auckland City has developed a set of standard drawings indicating their design preferences for bus lanes, mainly focussed on signage and marking features. However, there are many design issues that a national guideline could give consistent guidance on, as follows.

<u>Bus Congestion</u>
The number of buses and passengers to be accommodated needs to be confirmed, as this defines the length of bus stops, particularly at terminals. Bus catchup, or platooning is quite common, especially in commuter peaks. Platoons of 5 buses or more can occur regularly on some Auckland routes, overtaxing even extensive bus stops.

When demand for bus stops exceeds the available kerbside space buses queue up in the lane prior to the stop, which can disrupt intersections.
Platoons of more than two buses arriving at once make it difficult for passengers to flag down the service they want, which is stressful. Buses may also attempt to take gaps in the line of buses at a stop vacated by a preceding bus. In attempting to manoeuvre into a vacated spot they often end up with the rear of the bus obstructing the adjacent lane, affecting traffic operation. This is difficult to address unless buses are forced to pick up at locations within the stop defined by their route, and the actual bus stop locations are suitably separated.

This issue may be beyond the scope of a simple guideline, and in depth traffic study is required in areas of high bus and traffic flows and congestion. Nevertheless, where bus services are running frequently, say at less than five minute intervals, recessed bus bays should be considered in conjunction with bus lanes. The benefit of pull in bays may reduce with the presence of HOV's.

In relation to the demand for kerbside space, this might be improved by reducing loading times. Cashless systems, where pre-purchased cards or tickets are machine read upon alighting, are much quicker than cash based systems, and permit passenger entry at both front and rear doors.

Operating Speeds and Lane Width
As with motorway shoulder lanes, buses can develop significant speed differentials from adjacent lanes. This is made worse if motorbikes and HOV's also use the lane, as such vehicles are less visible than buses, and their drivers are less able to see over traffic in the adjacent general traffic lane.

Care needs to be taken to ensure adequate width is available to reduce the risk of collisions, particularly at sharp curves, at intersections where left turn stacking is restricted, and at accesses. This increases the opportunity for traffic in the bus or Transit Lane to identify traffic turning across their path or pedestrians crossing from behind stopped traffic, and to avoid them.

Overly narrow lanes generate infringements where a road curves, where lanes shift laterally, or with turns at intersections. Other sources of lane infringement include buses avoiding drainage elements, or roadside objects such as poles and barriers. Shyline clearance of one metre minimum should be provided.

Generally the narrowing of lanes to 3m alone does not adequately control speeds, yet significantly reduces intervisibility between bus or Transit Lane vehicles and those about to cross their path, including opposed right turns. Generally such turns should be minimised, and this may involve the use of turning restrictions at peak periods, such as on North Shore's Onewa Road.

Left turns tend to be sharpest, and are therefore more difficult for buses in constrained areas. Longer buses with large overhangs or articulated buses may track quite wide when making sharp turns, and the rear can strike traffic in adjacent lanes. The longer buses also have greater wheelbases, and can track across pedestrian aprons where corner radii are small. Tracking implications should always be checked at design stage, and turning lanes made wide enough to accommodate bus turning.

Pedestrian Crossings

Uncontrolled and zebra pedestrian crossings should be avoided on roads with more than two lanes in one direction, to avoid pedestrians stepping out from behind vehicles in a stationary lane into the path of others in a moving lane. However, problems with HOV's proceeding through a signalised crossing on Onewa Road appear to have been a problem, as PW-64 flashing lights have been added. In general this approach is not recommended if good visibility is available to the signals and markings. One possible solution to try first is to mark the limit line well back from the crossing.

Presence of Bicycles

Overseas literature indicates that the minimum desirable lane width for shared bus and bike lanes is 4.5m, with a minimum of 4.2m. The reason for this approach is that bikes operate at significantly slower speeds than buses, particularly where gradients and longer gaps between stops occur. Therefore buses attempt to overtake cycles, which is very intimidating to cyclists, and result in them being run into the kerb.

Cyclists also have difficulty getting past buses stopped in narrow lanes to pick up or set down passengers. Cyclists are forced to wait for the bus to move on, leaving them in a cloud of exhaust fumes, or to attempt risky overtaking in adjacent traffic lanes. Where cycles attempt to pass the bus on the footpath they can come into conflict with passengers alighting, or waiting to board.

Restrictions on Type of Vehicle Permitted

A lack of consistency has been noted by some motorists caught using bus lanes, as in local roads bicycles, motorcycles, and sometimes HOV's can use the priority lanes. However, on motorways, bus bypasses and bus advances, use is restricted to buses (and bicycles at some bus bypasses).

Taxis, Airport Shuttles (minibuses) and private bus services also argue that they should be entitled to use priority lanes. Whichever restriction is imposed on use, it needs to be clearly indicated to drivers, primarily through the use of signs. Symbolic signs are preferable to English language messages.

Currently most authorities restrict HOV use to vehicles with at least three passengers (HOV3 or T3).

Left turns (kerbside lane)

Priority lanes are discontinuous at intersections, similar to motorway bus shoulder lanes at on and off ramps. However, owing to lower operating speeds, local road priority lanes can end quite close to intersections, thereby maximising the benefit to buses. The proximity of the priority lane end to an intersection limit line should consider the stacking requirements for left turns.

Some authorities allowed private vehicles to share the bus lane for up to 50m before they turn into an entrance or side road. More recently, the Auckland City standards have provided full bus lane markings right up to minor side road intersections.

Priority Controlled Turns Out of Side Roads
Care needs to be taken at priority controlled turns out from side roads, as these can creep forward into bus lanes, and come into conflict with buses travelling at 50 – 60km/h. This can occur at signals with left turn slip lanes under Give Way control, especially if curvature on the major route makes it difficult for drivers to judge their relative position. For safety reasons it may be preferable to consider bringing left turn slips under signal control at intersections.

Right Turns Into Side Roads
Opposed right turns across multiple lanes often have little visibility around congested traffic, creating a risk of collision with traffic moving in kerbside priority lanes. Options to be considered include banning right turns, possibly during problem periods only, and Keep Clear markings.

Problems at an intersection on the North Shore were addressed by banning the turns in the morning peak. A line of temporary soft hit posts are installed each morning to reinforce the ban.

Enforcement Opportunities
Enforcement on local road priority lanes tends to be carried out by local authorities using specially trained and authorised personnel, with the assistance of video cameras. This obviates the need for separate enforcement lay by areas. Auckland City and North Shore City currently enforce their lanes in this way, with great success. Previously Police enforcement was less consistent, and relied on the use of kerbside space in side roads.

Ride Issues
Stormwater catchpits, LATM, roundabouts and protruding side road crowns all affect bus ride, and can suddenly throw standing passengers off their feet, or into seats and posts in the bus. Where bus lanes are being installed, care should be taken to address these issues, to make the bus experience as comfortable and attractive as possible.

Bus Boarders (Build Outs)
Dense traffic on busy roads delays buses rejoining the traffic stream from a stop, particularly on routes where traffic signals give rise to extended periods without gaps in traffic. Indented stops and the presence of parked vehicles make the problem worse.

A solution is to provide a bus boarder, essentially a kerb build-out that allows buses to stop without pulling out of the kerbside lane. This has obvious ramifications for following traffic, just as stops in kerbside lanes do. The solution is best achieved where only one wide lane can be achieved, allowing through traffic around stopped buses without centreline infringement. Bus boarders can improve both bus and general traffic safety and operation.

Bus boarders can be built out slightly less than the width of parking either end in constrained situations, but this can reduce the effectiveness of the boarder and increase the bus approach and departure angles. Angled boarders can be used where parking obstructs bus entry to a stop, but the exit is free of parking issues, such as when there is a downstream intersection or bus lane. Care also needs to be taken with lighting, road drainage, as well as avoiding creating pedestrian trip hazards, and ponding in the widened footpath.

Clearance to canopies

Buses can be tall and lean over the kerb in the vicinity of 150 to 200mm as a consequence of normal road crossfall, and more with steeper crossfalls. Bus bodywork wider than wheel tracks, and the effect of front and rear overhangs significantly increases this, so checks should be made that clearances to footpath canopies and bus shelters are achieved. Nevertheless, it is desirable to minimise the gap between canopies and stopped buses to maximise weather protection to bus users waiting to board. Further investigation is required to determine suitable clearances, which vary according to crossfall, and bus approach angle.

Signage and Markings

Auckland City's Standards for Priority Lane Signage, Road Marking and Road Surface Colouring of Priority Lanes gives some guidance for installing priority lanes. Some recent developments include doing away with a plethora of clearzone and parking signs when priority lanes are installed and signed. Doubtless it is a living document, and will evolve to take on board further issues as they arise, such as geometric standards for bus advances.

A Summary – Some General Concepts

Some issues arising with the development of bus priority facilities indicates the potential benefit of having a readily available New Zealand Guideline for Design and Operation of Bus Priority Measures. This would be of particular benefit to those RCA's just starting to develop these measures.

While some overseas publications offer good guidance, they can be difficult to get hold of, and may not be totally suited to the New Zealand situation. Hence the benefit of a national guide. It is pleasing to see development of a design manual is underway in Auckland, though nationally not many RCA's and consultants may be aware of it. It would be beneficial if the results were made commonly available to RCA's and their designers.

In addition to the guidance available from available references, the following general concepts are proffered :

- Provide clear guidance, preferably with symbolic messages, and keep it simple. The entry to bus priority facilities is a key area, and worth investment of extra markings (e.g. coloured surfacing) and signs.

- Ensure there is adequate width to accommodate all users, to allow early identification and avoidance of conflicts, and to avoid intimidating the more vulnerable users

- Avoid large speed differentials between adjacent lanes. Where this cannot be avoided consider methods of maximising intervisibility at conflict points like intersections, major accesses, pedestrian crossings

- Maximise the quality of bus ride, to avoid sudden changes in camber that can throw standing passengers

- Check vehicle tracking, particularly on sharp turns, or where stops accommodate several buses, to ensure buses can track within their own lane

- Avoid ponding in dish channels causing buses to splash pedestrians

Further sources of guidance include:

London Buses, Operational and construction guidelines

UK Dept for Transport, Keeping Buses Moving A guide to traffic management to assist buses in urban areas, ISBN 0 11 551914 9

Transport for London, Intermodal transport interchange for London best practice guidelines

London Bus Initiative Partnership, Bus stop layouts for low floor bus accessibility

Institution of Highways & Transportation, Planning for public transport in developments, ISBN 0 902933 32 9

Auckland Bus Priority Steering Group*, Standards for Priority Lane Signage, Road Marking and Road Surface Colouring of Priority Lanes (unpublished)

Auckland Bus Priority Steering Group*, Standards for Special Vehicle Lanes (unpublished)

* Auckland City, North Shore City, Waitakere City, Manukau City, Transit New Zealand, Land Transport New Zealand, Police, Bus & Coach Association