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Paper title: **David and Goliath – bikes and buses together without throwing stones**

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Abstract (200 words):
Buses and bikes are at opposite ends of the spectra of size, mass and manoeuvrability but frequently operate in the same road space, adjacent to the kerb and at intersections. Both are effective alternatives to private cars for travel in urban areas and are promoted on this basis, but can come into conflict as well as working together. Urban transport strategies focus heavily on reducing growth in car traffic, for social, environmental and economic reasons. A reasonable presumption for the 'green' modes of transport (walking, cycling and public transport), therefore, is that one should not be given priority at the expense of another, and that where a project may have this effect it should be redefined to ameliorate the adverse impact or provide an appropriate alternative. At the strategic level, interaction of bikes and buses is often seen in terms of the bicycle, as a feeder mode, expanding the catchments for public transport, although the emphasis has most often been on train stations rather than bus stops. This paper presents the results of a study sponsored by the Australian Bicycle Council and Austroads to identify means of enhancing synergies and minimising conflicts between buses and bikes within the road network.

Introduction

Buses and Bikes are at opposite ends of the spectra of size, mass and manoeuvrability but often operate in the same road space, adjacent to the kerb and at intersections. Both buses and bikes are effective alternatives to the private car for travel in towns and cities and are actively promoted by governments, but they can come into conflict as well as working together.

The Australian Bicycle Council commissioned ARRB Transport Research to develop guidelines for the management of interactions between buses and bikes in the road network. These guidelines were to take the form of a 'Toolkit' that could be made available electronically, as well as in hard copy, including via the Australian Bicycle Council website (http://www.abc.dotars.gov.au/bus-bicycle_interactions.htm).

Identifying the issues

In consultation with the project Steering Committee, ARRB identified a range of key stakeholders from the bicycle and bus sectors from whom information was sought in response to the following questions:

- What key issues arise from interaction between buses and bikes in the road network?
- What options are there for resolving conflicts or adding value to beneficial interaction?
- What existing standards or guidelines might apply to these issues?
- Do you wish to nominate any specific situations that might be useful as case studies, including examples of both good and bad practice?

A survey form was also circulated at the 'Connecting Cycling' Conference in Canberra, 20/21 November 2003, and was posted on the Australian Bicycle Council website.

Some broad issues

Bicycles and buses represent almost the extremes of the spectrum of users of the travelled-way part of roads in cities, yet they often operate in the same part of the roadway. Cyclists tend to use the kerbside lane of roads, except where making a vehicular right turn from the centre of the road. Buses also operate primarily in the kerbside lane because of the need to pick-up and drop-off passengers at bus stops.

The cyclist is small and vulnerable; a bus is large and potentially threatening. The cyclist presents a small visibility profile. The design of buses may mean that the driver has poor visibility with respect to certain areas surrounding the bus, where a cyclist might be located. Although the increasing use of more upright ('mountain bike') styles of bicycle may have enhanced cyclist visibility, recumbent cycles pose particular visibility problems especially in areas alongside large vehicles with high-mounted mirrors – not just buses.

The general perception is that cyclists travel slowly; bus drivers may underestimate the speed of a cyclist being passed and pull in towards the kerb before there is clear space to do so.

Both buses and bicycles may have specific parts of a roadway set aside for their specific use (bus lanes and cycle lanes). However, neither of these is necessarily exclusive and conflict can result. Where they are exclusive, the result can be that the other user (often the cyclist) is forced into a more dangerous situation in faster-moving and more complex traffic. The

Australian National Road Rules, as adopted in Victoria, Western Australia, Tasmania, the Australian Capital Territory and the Northern Territory, bicycles are not permitted in special-purpose bus lanes unless signed as permitted. However, in New South Wales, Queensland and South Australia, bicycles are permitted to use bus and transit lanes, unless there is a sign prohibiting them.

Specific issues of visibility and manoeuvrability are likely to occur at intersections, whether or not these include special provision for either bicycles or buses. The issue of predictability is also important, so that all users of bicycle and bus facilities can have certainty about situations that are likely to arise.

Bus-bicycle interaction in the road system may have three major types of consequence:
- infrastructure capacity requirements;
- operational performance, such as safety, travel times and predictability of level of service;
- perceptions, particularly by cyclists, that lead to changes in travel behaviour, including mode shift (not using the bicycle) and using alternative routes.

Many of the issues facing cyclists in their interactions with buses in the road network also face them with other motorised road users, especially heavy vehicles. This study, whilst it focuses specifically on buses, also delivers benefits in respect of those broader interactions.

Transport strategies

Most urban and metropolitan transport strategies agree that the historical trend of increasing use of the private car for personal travel has to be reversed for a range of reasons, including:
- Congestion
- Local and global (greenhouse) environmental impacts
- Urban sprawl and land use impacts
- Road and transport safety
- Increasing cost of providing and maintaining transport infrastructure and services
- Social inclusion and equity.

Some strategies set targets for reduced car use relative to the ‘business as usual’ expected outcome (eg MTS, 1995; Brisbane, 2003). Others are less specific but are equally clear on the direction (eg South Australia, 2003). Where targets have been set, they have been powerful drivers of new initiatives, such as voluntary travel behaviour change programs (TravelSmart) that have important beneficial impacts on the levels of both cycling and public transport use.

Whilst strategies are based on the need to achieve substantial increases in both cycling and public transport (and other alternatives to the private car), reference to the inter-relationship between cycling and public transport is usually in terms of the bicycle providing a convenient and effective means of expanding the catchment for public transport through:
- Provision of bicycle parking and secure storage at bus stops and stations, and
- Carriage of bikes on buses.

Both public transport and cycling components have commonly included reference to dedicated facilities (paths, cycle lanes, bus lanes, transit lanes) and other forms of priority (eg at signalised intersections) without recognition of the potential for conflict either:
- Directly between the modes where they share the same space, or
- Between cyclists and general traffic where exclusive bus facilities are established.

This is not merely an Australian phenomenon. The *Mayor's Transport Strategy for London* (TfL, 2001), possibly the most comprehensive and radical integrated transport strategy for a major urban area, deals with bikes (section 4j) and buses (section 4f) separately, but adds that *measures can be used individually or collectively to support the policies and proposals of the Strategy. Of particular importance is the use of street space allocation to assist road safety initiatives; support bus, pedestrian and cyclist initiatives; and to ensure that initiatives, such as the proposed central London congestion charging scheme, do not result in diverted traffic using unsuitable streets* (current author's emphasis). However, there is no implication that there might be conflict between the bus, pedestrian and cyclist initiatives.

Bicycle strategies and plans

The Australian national cycling strategy (Austroads, 1999a) mentions bikes and buses in terms of increasing multi-mode trips involving bicycles and public transport (Strategy 3.4), but does include, without comment, an example of bus-bike co-existence in the roadway.

At a State level, references to buses in bicycle strategies and plans are few and usually in similar terms to the parent transport strategy (see, for example, the WA *Bike Ahead* Strategy (Transport WA, 1996a, p26)). The recently released *Queensland Cycle Strategy* (Queensland Transport, 2003a) deals with bicycle/public transport issues in the following terms: *Links with public transport can extend the range and usefulness of bicycles, especially for commuting, inter urban trips and tourism. The bicycle can be used at both ends of public transport trips, by being parked at a station or in some circumstances carried with the passenger* (p31).

The UK National Cycling Strategy (DoT, 1996) also focuses on linking bikes and public transport, although it does make specific mention of:

- The potential for traffic management and highway engineering to improve conditions for cyclists, whilst emphasising that *if engineers do not explicitly plan for cyclists, traffic management can make cycling conditions worse, endangering cyclists and discouraging people from cycling* (p15); and
- The need to address traffic engineering, vehicle design and education of drivers to reduce the disproportionate incidence of serious injuries and fatalities caused by crashes with heavy goods vehicles (p17). There is no mention of buses, but the issues raised appear to be equally applicable to buses as to heavy goods vehicles.

Bicycle network plans generally either do not mention buses and public transport or do so only in the context of cycle access to public transport (see, eg, RTA, 1999; Queensland Transport, 2003b; Transport WA, 1996b; ACT, 1997), in terms of providing routes to access public transport access points, facilities at bus/train stations and/or carriage of bikes on buses.

The sole reference to buses in the New Zealand walking/cycling draft strategy (NZ, 2003) is: *Whether it is accessed on foot, by private motor vehicle, in a bus, or on a cycle, all road users share the same road network. Ensuring the network works efficiently for all modes and users - cyclists and pedestrians as well as motor vehicle users – presents a significant, but essential, challenge for those who plan, design, manage and fund the transport system* (p20). The draft strategy breaks new ground in stating: *Road environments that are safe for pedestrians and cyclists also benefit public transport users, and tend to be safer for motor vehicle use* (p9).

Many references to buses in bicycle strategies and plans do not relate to the road network but to ancillary facilities such as bus/train stations. However, the UK National Cycling Strategy (1998) does refer to *shared use of the carriageway between cyclists and public transport vehicles can justify better segregated priority access to town centres. Bus and cycle lanes, shared bus/cycle streets and bus/cycle gates are three examples of such priority measures*.
A recent exception, however, is the Central Sydney Bikeplan (Sydney, 2003) which includes bicycle usage of both existing and proposed bus lanes as an integral part of the cycle network. This includes minimum-width bus lanes as well as 1.0m-wide bikelanes delineated within a 4.0-metre bus-bicycle lane. However, in some locations, alternative routes are designated where the volume and complexity of bus movements may make cycling dangerous.

Public transport strategies and plans

Reference to bikes in bus/public transport strategies and plans is usually in similar terms to the parent transport strategy. *Better Public Transport* (Transport WA, 1998) deals with bicycles only in terms of bicycle parking at stations and carriage of bikes on buses and trains.

Overseas, the bicycle-related focus of public transport plans has also been on the complementary use of bicycles in conjunction with public transport to expand the range of transport opportunities. The United States Federal Transit Administration (FTA, undated – accessed 27 November 2003) puts it in the following terms:

- ***For Bicyclists.*** *Access to transit allows bicyclists the opportunity to make longer trips.*
- ***For Public Transportation Providers****. Improving bicycle access attracts new transit riders. Bicycle access expands transit's catchment area … Providing secure parking for bicycles at transit stops and stations is less expensive than … for automobiles.*
- ***For Livable Communities****. Bicycles and transit provide more mobility options to everyone, particularly those who because of age, disability or income are unable to drive. Less automobile traffic … contributes to a safer, quieter, and more pleasant environment.*
- ***For Everyone****. Safe and convenient transit service and bicycle facilities attracts more passengers and increases the viability of transit service. Fewer trips by automobile reduces polluting emissions.*

Guidelines and standards

Provision for cyclists in the road network is primarily by reference to Austroads *Guide to Traffic Engineering Practice (GTEP), Part 14, Bicycles* (Austroads, 1999b). A parallel guide (*Part 16: On-Road Public Transport*) is currently under development by ARRB Transport Research for Austroads. Bicycles and public transport are also dealt with in other volumes of the Guide to Traffic Engineering Practice, including:
Part 6: Roundabouts
Part 9: Arterial Road Traffic Management
Part 10: Local Area Traffic Management

The only substantial reference to buses and bikes in GTEP Part 14, *Bicycles*, is:-
Where the left hand lane of an urban arterial road is a bus lane, it is unreasonable for cyclists to use the normal traffic lane and they should be provided for as follows:

- *in congested city areas where peak period traffic speeds are about 40km/h and space can be made available it may be preferable to provide a 1.5 metre wide bicycle lane to the*

right of the kerbside bus lane. This would normally result in a combined bus/bicycle lane width of 4.0 – 4.5 metres;
- *through the sharing of narrow (eg minimal width) bus lanes under very congested conditions. In general this approach is only applicable where buses do not stop in the bus lane; or*
- *where the speed of buses is relatively high (up to say 80km/h) a shared lane 4.5 – 5.0 metres wide is necessary so that cyclists and buses can safely overtake each other within the lane.*

The following factors need to be considered in choosing the most appropriate solution for a route:
- *the preferences of cyclists who use the route;*
- *the speed of buses and other traffic;*
- *the location of bus stops;*
- *the frequency with which buses stop in a length of road; and*
- *the available width.*

Signs erected to legally define the bus lane should also make it clear that cyclists are permitted to use the lane unless this is covered in State or Territory traffic regulations (p34).

For other purposes, buses are not separately identified, despite the differences from other heavy vehicles in terms of operational requirements (eg frequency of stopping at bus stops; exiting/entering the traffic stream) and performance (eg acceleration; deceleration).

State-based bicycle guidelines, with the exception of New South Wales (RTA, 2003), pay little, if any, attention to the specific interaction between buses and bicycles, as distinct from bicycle interaction with other motor vehicles.

Most overseas guidelines also pay little attention to the specific issue, largely on the basis the first design response is to separate bicycles from motor vehicles. However, the Irish guide (DTO, 1997) sets out recommendations for:
- facilities for buses and cycling on the same roadway
  - physical segregation;
  - visual segregation;
  - shared use of bus lane – generally recommended for bus speed <30km/hr frequency <10/hr (in same direction) and low cycle volumes. However, ... *cyclists should always have access to with-flow bus lanes if no other cycle facilities are provided.*
  - contra-flow bus lane with cycle track
  - streets used predominantly by cyclists and buses
- bus lay-bys, bus stops and cycle facilities
  - bus stops with physically segregated cycle facilities
  - bus stops with on-road cycle tracks
  - bus stops on the carriageway
- parking facilities for cyclists near public transport

The guide does not provide strict warrants for volumes or speeds but suggests thresholds for the various types of treatment. It also includes comprehensive dimension recommendations.

Bus-bike crashes

Conflicts between buses and bicycles may result in crashes, but such crashes are infrequent. In Western Australia, there was an average of 12 bus-bike crashes per year (1.5% of bike crashes) reported to police from 1987 to 1996 (Hendrie et al, 1998). A bus was involved in 1.8% of reported bicycle crashes involving another road user (Hendrie, et al, 2000).

Data on bus-bike crashes are focussed on the fatality and severe injury end of the spectrum. Data on fatal and serious injury bus-bike crashes from 1989 to 1996 (ATSB, 2003) show that:

- 1.0% of fatal/serious injury cycle crashes reported to police also involved a bus; and
- 5.6% of fatal/serious injury bus crashes reported to police also involved a cyclist.

This clearly illustrates the high vulnerability of cyclists in a bus-bike crash. The number of bus-bike crashes resulting in fatality/serious injury varies, Australia-wide, significantly from year to year, as does the proportion of fatalities (Figure 1). This is not unexpected in relation to events that occur in small numbers. ATSB (2003) also shows that:

- Fatalities were 1 in 7 personal outcomes from reported bus-bike crashes involving fatality and/or serious injury (Figure 2); and
- Fatalities were most likely to arise from angular or rear-end crashes, with a high proportion also arising in unknown or unclassified situations (Figure 3).

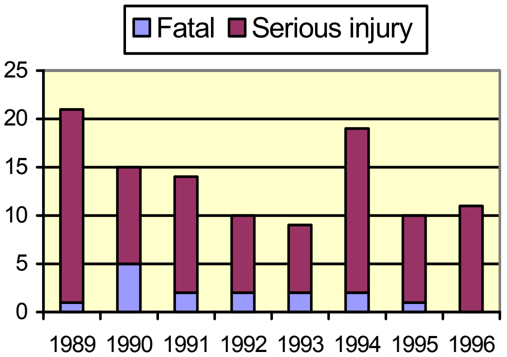

Figure 1 Bus-Bike Crashes, 1989-1996: Australia (Source: ATSB, 2003) **[N = 109 or 13.6 per year]**

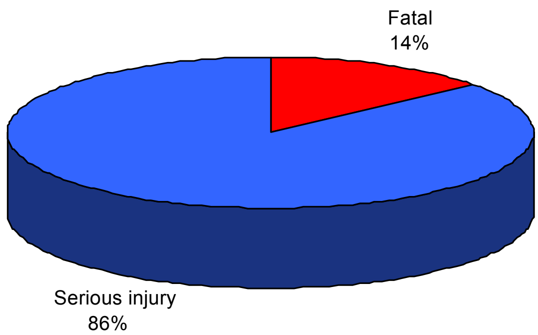

Figure 2 Fatalities and Serious Injuries in Bus-Bike Crashes, 1989-1996: Australia (Source: ATSB, 2003) **[N = 112 or 14 per year]**

	Fatal	Severe Injury	Total
Angular	10	59	69
Head-on	0	5	5
Rear end	2	16	18
Struck parked vehicle	0	5	5
Other/Unknown	3	12	15

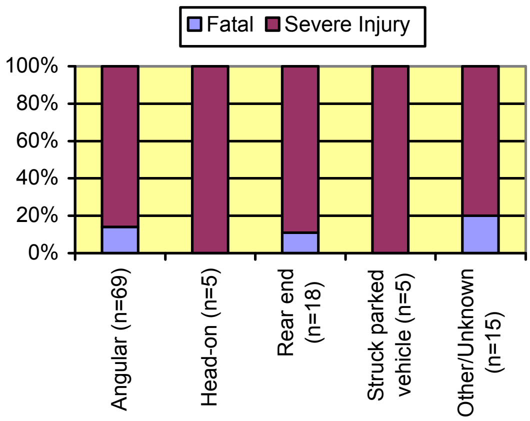

Figure 3 Fatalities and Serious Injuries in Bus-Bike Crashes, 1989-1996: Australia – by type of crash (Source: ATSB, 2003) **[N = 112 or 14 per year]**

The ATSB data for 1989-1996 also show that:

- 55% of fatalities/serious injuries resulting from reported bus-bike crashes occurred at intersections; and

- 42% of fatalities/serious injuries resulting from reported bus-bike crashes occurred at other locations (Figure 4).

Not surprisingly, of the three major types of location, the proportion of angular crashes was highest at X (four-way) intersections. However, there was no difference between the proportions for T-intersections and non-intersection locations (Figure 5).

The high proportion of angular crashes at non-intersection locations indicates that a substantial proportion is related to lateral movement of buses in the roadway.

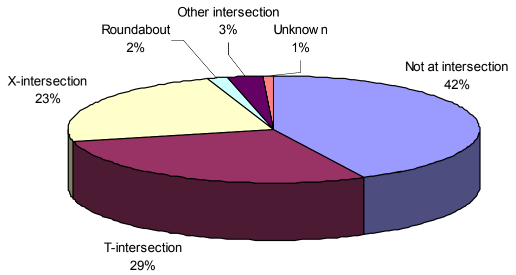

Figure 4 Fatalities & Serious Injuries in Bus-Bike Crashes, 1989-1996: Australia – by location of crash (ATSB, 2003). **[N = 112 or 14 per year]**

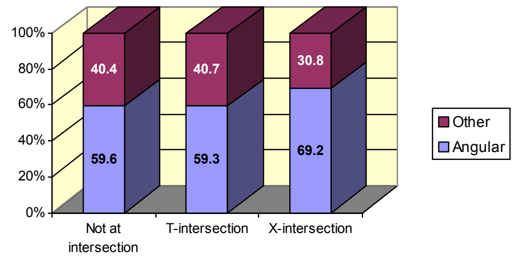

Figure 5 Fatalities & Serious Injuries in Bus-Bike Crashes, 1989-1996: Australia – Crash Type by Location (ATSB, 2003). **[N = 105 or 13 per year]**

Issues for cyclists

The identification of bus-bike interaction issues for this project was primarily on the basis of the consultant's and the Steering Committee's knowledge and experience plus a survey of key stakeholders in the bicycle and bus sectors. It is, however, also useful to look at the issues that have previously been document, unprompted, in other forums.

An important focus for cyclists has been to ensure that new initiatives to improve the operating environment for public transport do not inadvertently make things worse for cyclists. As Bicycle Victoria (2003) stated: *it is important that the push for upgraded public transport facilities is not at the expense of cycling* and *the strategy must support and encourage the complementary benefits of integrating cycling and public transport options*.

A search of Australian bicycle websites indicated the following issues to be of concern:

- Carriage of bicycles on buses and trains
- Bicycle parking at bus and train stations
- Bus stops and bike lanes
- Bus shelters impeding shared paths
- Use of bus lanes by cyclists
- Criteria for shared bus/bike lanes and for separate facilities
- Bus driver training

The Bicycle Federation of Australia Policy 1997:2, Bicycles on Public Transport (BFA, 1997a), has the objective 'to extend the range and convenience of cycling, public transport authorities permit and in some cases, promote the carrying of bicycles on their public transport services'. However, the policy statements themselves can be seen to apply equally to bus transit infrastructure, such as bus lanes:

1 *All public transport systems shall be designed to be accessible including for cyclists to allow and encourage use of the system by all people and to avoid discrimination.*

2 *Provision of designed facilities on public transport systems will overcome current operational and spatial conflicts and shall be an essential requirement for all new or upgraded public transport infrastructure and services.*

More generally, the BFA states, with respect to bicycles on roads (BFA, 1997b):
1 *Provide adequate operational space for cyclists on all roads and streets to provide an equitable alternative to car travel.*
2 *Where adequate road space cannot be provided either solely or shared, speed limits and road design shall provide adequate operational space to promote cycling, walking and public transport to the benefit of local amenity and environment.*

In the United Kingdom, the Cambridge Cycling Campaign (2001-2003) has documented several issues relating to the development of bus lanes making conditions worse for cyclists. For two bus lane proposals, *if these two bus lanes were to be installed, any advantages would be outweighed by damage to pedestrian and cycle facilities* (CCC 2001-2003).

Drivers' perceptions of cyclists

Road design and traffic management primarily deal with the objective realities of the road system and of road use. In practice, however, the actual safety and convenience of road use and the safety and related outcomes depend heavily on user perceptions of both the road and traffic conditions and of other users.

There is a significant difference between the attitudes towards cyclists of car drivers who are also cyclists and others who are not (AA, 1993). Research suggests that drivers who were also cyclists were *better able to distinguish between different types of cyclists, separating the good from the bad* [but] *on the whole … the attitudes of those who cycled did not vary significantly from those who did not cycle. They tended to see things from the driver's perspective and could be just as negative about cyclists as other drivers who were non-cyclists*. In general, 'drivers who cycle or have pro-cycling views are less critical of cyclists and drive more considerately, but the differences are not large' (Basford et al, 2002).

When asked to nominate three categories of road users that annoyed them:
- 47% of UK drivers cited taxis;
- 37% cited buses and coaches;
- 30% cited cyclists; and
- 26% nominated vans; and
- 25% nominated trucks.
- Only 13% nominated 'cars', which is consistent with a well-established inclination to regard the behaviour of 'out-group' members more negatively than the behaviour of 'in-group' members (Basford et al, 2002, pp13/14).

Drivers believe that cyclists are not aware of the fact that their small size can make them difficult to see. Drivers of larger vehicles (heavy trucks and buses) report that this 'tended to infuriate them' (Basford et al, 2002, p7). The same study reports that: *When prompted, all the professional drivers, regardless of whether they were carrying goods or passengers, tended to be less accepting of cyclists' presence on the roads they were using. They felt that their livelihood was being interfered with – particularly if they were held up by a cycle, which was obviously slower than other vehicles, within their lane. It was reported that being caught behind a cyclist added further to the pressure on their work schedules"* (p7).

Issues and guidelines

Bicycles and buses can interact in many ways, both detrimental and beneficial. The research and consultation identified 24 issues for which some guidance would be beneficial. These are listed below, with a brief outline of both the issue and the recommended approach to adopt in considering proposals that may affect the co-existence of bicycles and buses within the road network.

A further issue, *bikes on buses*, was not addressed as it was seen as being beyond the scope of this study. An important trial is underway in Brisbane.

Issue	Outline	Recommended Approach
Network Planning	Most cycling and most bus services utilise the surface road system, which is essentially a common-user system, although within it parts of individual road carriageways may be set aside for the exclusive use of one or more classes of users (eg bike lanes and bus lanes). Conflicts between users can degrade the cycling experience at specific locations which, in turn, may reduce the attractiveness of cycling over a range of areas and routes of which such locations form part.	For many types of cyclists, coincidence of cycle and major bus networks should be kept to a minimum, unless providing visually- or physically-separated facilities for cyclists. Any alternative routes for cyclists should offer a higher level of service, including consideration of distance, than the one rejected on the grounds of sharing with buses. Where sharing by bus and bicycle is not desirable, consideration should be given to changing bus or cycle routes in an integrated local and regional approach. For commuter cyclists, arterial roads, which often carry a substantial number of buses, form logical and convenient routes. Bus route planning should recognise the need to provide arterial routes for cyclists. Where bus priority is being considered for part of an existing or planned designated bicycle network, the bus proponent should have the responsibility to ensure that level of service is maintained for cyclists.
Continuity and Consistency	Continual changing of conditions for cyclists along a route fosters uncertainty and unpredictable behaviour, particularly where conditions actually change, and will act as both real and perceived barriers to use by cyclists.	Bus and cycle priority should be considered on a route and area basis as well as on the basis of specific situations. Priority should be addressed on an integrated basis, for all road users and local as well as regional trips, providing benefits for all environmentally-friendly modes (including cycling and walking). *Red Routes*, first in London and now in the West Midlands and Edinburgh's *Greenways* provide useful examples of best practice.
Cycle Audit	Public transport infrastructure and priority measures that aid public transport can have negative impacts on cycling, causing delays, inconvenience and increased risk of crashes. There is often no systematic process to ensure that, before measures to promote and assist public transport are introduced, steps are taken to overcome adverse cycling impacts and, where possible, improve cycling facilities.	Proposals that have potential impacts on the convenience or safety of cyclists should be subject to a cycle audit process (see, for example, Austroads, 1999, Appendix A). To make cycle audit more appropriate to proposals for bus priority, the following additional items should be considered: • If a bus lane is proposed, will cyclists be able to use it? Will it be wide enough for buses and cyclists? If not, is there an alternative route suitable for cyclists? • Have bus stops and bus shelter locations been designed to allow the safe passage of bicycles? • Where buses are required to turn next to cyclists, does swept path of the buses encroach upon the cyclist space? • If 'B' bus priority lights are proposed, has consideration been given to the needs of cyclists?
Shared Bus-Bike Lanes	The inherent speed differential between these modes, and the	Bus/cycle lanes should be of sufficient continuous width (min 3.7m; desirable 4.2m) to enable overtaking within the

Issue	Outline	Recommended Approach
	frequent stopping of buses, often leads to 'leap-frogging' or bus delays. Such leap-frogging is difficult with minimum-width bus lanes and heavy adjacent general traffic. The issue is, therefore, should shared bus & cycle lanes be wide enough for overtaking, or should this be discouraged?	lane. If the required width is not consistently available, localised widening can provide occasional overtaking opportunities – for example, at bus stops, which would also allow cyclists to pass buses stopped to pick up or drop off passengers. Bus/bicycle lane widths between 3.0m and 3.7m are not recommended as this would encourage attempts at overtaking within the lane where there is insufficient margin for safety.
Separate Bus and Bike Lanes	When parallel bus and cycle lanes are provided within the roadway, they may be either physically or visually separated, and either one may be located adjacent the kerb. If the cycle lane is next to the kerb, there will be increased issues with bus stop conflicts. If the bus lane is next to the kerb, cyclists will have traffic on both sides.	The cycle lane should generally be located adjacent to the kerb. Solutions to the issues regarding conflict at bus stops are discussed under *Cycle Lanes at Bus Stops*. Where a bus lane is established away from the kerb (for example to allow for all-day operation in conjunction with off-peak car parking), it may be possible to install a combined bicycle/car parking lane if there is insufficient roadway width for separate parking and bicycle lanes. Cycle lanes or bicycle/car parking lanes adjacent to bus lanes should be designed, constructed and signed in accordance with Austroads (1999, Chapter 4).
Bus Station Entry/Exit	The entry and exit points for bus stations inevitably have high concentrations of bus movements often in complex environments involving turning and other vehicle manoeuvres.	It is desirable for cyclists to be provided with a separate access route into or past modal interchanges, rather than to interact with buses and/or pedestrians. Careful attention will need to be paid to visual or physical separation of cyclist and other space, including access for buses and bus passengers/pedestrians. It may be desirable to have grade separation where the level of conflict is high.
Bus Left Turn at Intersections	Bus turning movements can pose 'blind-spot' and 'swept-path' issues, especially where the bus is making a left turn from a dedicated left-turn lane and lane geometry is inadequate for the bus to remain totally within the turning lane.	All buses should carry the pictorial 'do not overtake turning vehicle' sign at both left and right rear corners of the vehicle at cyclist eye-height. Intersections/junctions with left-turn bus movements should be designed to the geometric design recommendations of the Austroads (1991) Guide to Traffic Engineering Practice, Part 5, Intersections at Grade. In some cases, it may be necessary to set back the stop line on the intersecting road.
Roundabouts	Roundabout design is a key issue for buses and bicycles both in the context of their interaction, and individually. The appropriate solutions for one might compromise safety and convenience for the other. The issues may vary depending on the size of the roundabout.	On single-lane roundabouts, care should be taken to ensure that the design facilitates bus movement, especially for right turns, without distracting the driver from the possible presence of cyclists. Design should preclude a bus passing a cyclist when negotiating the roundabout. It may be desirable to indicate that cyclists should occupy a position away from the kerb, to prevent passing by buses (or other vehicles). Each situation should be assessed individually to arrive at the most appropriate solution.
Bus Stop – No Cycle Lane	When a bus approaches a kerbside stop the driver may have to decide whether to overtake a cyclist and then pull to the kerb in front of him/her, or to slow down and wait for the cyclist to clear the bus stop. The cyclist may then	Bus stop location and design should take account of the extent to which buses stopping to pick up or drop off passengers will impede cyclists (and vice versa). Where the kerbside lane (whether a bus lane or a general traffic lane) is not wide enough for a cyclist to pass a bus safely, consideration should be given to localised widening of the lane or embayment of the bus stopping area. Embayment of the bus stop will also benefit bus operations when there are

Issue	Outline	Recommended Approach
	have to decide whether to manoeuvre around the stopped bus.	both stopping and non-stopping services.
Bus Shelters Impeding Shared Paths	Bus shelters that intrude on the travel space of cyclists on shared paths, either directly (ie encroaching on the path itself) or indirectly (reducing lateral clearances) will reduce the safety, convenience and comfort of the facility for cyclists. Bus stop furniture (posts, seats, etc) may intrude on the travel space for cyclists.	Bus shelters and other associated bus stop furniture should not intrude upon or restrict shared paths. Alternative locations may be necessary for bus shelters. Where bus shelters are being considered close to a shared path, the bus proponent should have the responsibility to ensure that the level of service is maintained for path users. Where no alternative suitable location is available for the bus stop furniture or the path, any intrusions into the path should be clearly delineated with line-marking and the bus stop furniture itself should be treated to maximise visibility to path users. The same applies to footpaths, since most jurisdictions allow cycling on footpaths by children up to the age of 13.
Cycle Lanes at Bus Stops	The issue here is similar to that for *Bus Stops (No Cycle Lane)*, except that the bus is always positioned further from the kerb on approach to a bus stop. When a bus is approaching a kerbside stop the driver may have to decide whether to overtake a cyclist and then pull to the kerb in front of him/her, or to slow down and wait for the cyclist to clear the bus stop.	Where a cycle lane lies between a bus lane and the kerb, the lane should be continuous across bus stops, even though the bus will need to pull to the kerb at stops. The road traffic laws allow a cyclist to leave a cycle lane to pass an obstruction, including a stopped bus. However, where a bus lane is adjacent, this requires that cyclists be allowed to use the bus lane. It is important that bus drivers pull close to and parallel to the kerb at stops to ensure adequate space for a cyclist to pass on the traffic side. Where frequency or duration of bus stopping and/or number of cyclists are large, consideration should be given to: • an embayed bus stop (behind the cycle lane); or • a cycle by-pass.
Local Area Traffic Management	Local Area Traffic Management (LATM) involves modifications to the structure, layout or design of local streets, with the primary objective of reducing the adverse amenity impacts of car traffic in residential areas. Such modifications can have adverse impacts on the suitability of the street for bicycle and bus use unless facilities are appropriately designed.	Where LATM treatments adversely affect buses and/or bicycles, consideration should be given to selecting a more suitable device or adapting it to minimise the effect. Some vertical displacement devices can be designed to enable bicycles to bypass the treatment. This may also be the case with horizontal displacement devices, such as slow points. It is however of paramount importance that cyclists remain visible to other traffic as they pass through the treatment, and that both modes can merge safely afterwards. Where only buses are allowed access between parts of the local street system, the facility should be designed to allow safe passage of bicycles and pedestrians. This can also be a useful approach in town and city centres.
Trams in Kerbside Lanes	Tram tracks in the kerbside lane are incompatible with the safe and convenient operation of bicycles. Tram lines in the roadway are a hazard for cyclists where they cannot be crossed at something approaching a right-angle.	Where kerbside tram operation is being considered, a separate cycle facility should be included as an integral part of the project. Such facilities should not reduce the level of service to cyclists (eg through loss of priority at intersecting streets or substantial detours away from the direct route). Where trams operate away from the kerb but the kerb is projected out to the tramline at stops, similar treatments to those for projecting bus stops should be considered.
Facility Design on Hills	Cyclists will travel more slowly on uphill grades and be more likely to be encountered	When designing bus and/or cycle networks or specific facilities (eg bus and/or cycle lanes) on gradients, the effect of those gradients on the speed differential between the

Issue	Outline	Recommended Approach
	by a bus seeking to pass. Cyclists will be less likely to be impeded by a bus. Conversely, downhill grades will decrease the frequency with which a bus encounters a cyclist and increase the frequency with which a cyclist may be impeded by a bus.	modes. Where there is opportunity for additional bus/bicycle space in only one direction, that space should be provided in the uphill direction unless the specific circumstances indicate otherwise. Gradient should also be allowed for in setting traffic signal phasing, including bus priority signals, especially where cyclists or other vehicles make hook turns.
Hook Turns	Cyclists may take longer to cross an intersection to the 'hook-turn' point at the left of the roadway and may not arrive until after the lights for turning/intersecting traffic have turned green. Where bus priority signals are in operation on the intersecting road, a bus driver may be unaware of a cyclist still in the intersection as the bus has been given a clear signal of priority.	At a signalised intersection, signal phasings should ensure that a cyclist legally passing a signal on entry to the intersection is able to reach the turn point, where he/she will be clearly visible to the drivers of intersecting vehicles, before the intersecting traffic receives a green light. Signal phasing must also avoid situations where cyclists cannot legally proceed after making the first stage of a hook turn and impede or are in danger from other traffic (eg a dedicated left-turn phase from the intersecting road). At an unsignalised intersection, consideration should be given to provision of a cyclist refuge, outside the normal traffic areas where a cyclist can wait for a safe and convenient gap in the traffic to make the turn while not impeding left-turning traffic from the intersecting road.
Cycle Use of 'B' Bus Priority Lights	Bus priority lights are usually approached by a bus lane (which may be used by cyclists), but regulations state that only buses can move when the signal is illuminated. Bus priority lights can be used to authorise movements not permitted to other vehicles, as well as to give priority timing.	Cyclists are not allowed to make use of 'B' bus priority lights, but an additional cycle lantern, operating on the same phasing, could be installed. Where cyclists are allowed, by this, access to the signal priority, detectors must be able to respond to a bicycle as well as a bus. Where the bus priority light authorises movements that may be unsafe, inappropriate or unnecessary for cyclists (eg access to a bus station or depot), advance warning and safe/appropriate transition to an alternative facility (cycle lane or shared path) shall be clearly provided and signed.
New Bus Facilities	New, dedicated, bus facilities in exclusive rights of way, provide opportunities for creating new cycle/pedestrian movement opportunities to and along the same alignment. These also enhance accessibility of bus stops/stations along the route. Dedicated busways may increase severance between places on opposite sides and reduce convenience of cycling if crossings are not adequate.	Wherever possible, new dedicated bus or transit corridors should be planned, designed and constructed as multi-modal 'green transport corridors', with specific provision for cycle movement along and across the primary bus facility. Because buses will be travelling at a relatively high speed, particular consideration should be given to: • separation of bicycle facilities from the busway/ transitway; • traffic control (especially on the crossing bicycle route) and sight lines (for both bus driver and cyclist) at cyclist crossing points. • Cyclist and pedestrian connections to nearby development and to bus stops/stations.
Bus Lane Regulations	Traffic regulations may exclude cyclists from bus lanes. Potential conflicts between bicycles and other vehicles are likely to be less in bus lanes than in adjacent general traffic lanes. However, cyclists operate more slowly	Cycle and bus stakeholders should work together to maximise level of service for the two modes collectively. This may be achieved through network planning as well as specific facility planning and design. Bus lanes should provide sufficient width for safe and convenient sharing of the lane by buses and bikes. Even where sufficient width cannot be provided, cyclists should be allowed in kerbside bus lanes unless there is a substantial

Issue	Outline	Recommended Approach
	than buses and may delay buses in a priority facility. There may not be safe and convenient alternative routes for cyclists.	reason to exclude them, for example: • the bus lane only serves a bus facility (depot/bus station); • the specific circumstances (eg number of cyclists/buses, impact of grades on cyclist speeds) would cause a substantial loss of benefits from bus priority. If it is proposed to exclude cyclists from a kerbside bus lane, the proponent should ensure that alternative provision is made for cyclists, either in the same roadway (eg with a marked cycle lane) or on a convenient alternative route.
Contractual and Commercial Imperatives	Bus operators under contract or franchise may be subject to financial penalty for late running. Customer service imperatives to avoid late-running. Cyclists are seen as slow-moving and likely to hold-up buses, especially where there is little need for buses to stop.	Network planning should ensure that cycle travel along a bus lane is minimised, both in terms of number of cyclists and the length of sharing between buses and bikes, where a lane wide enough for bus-bike sharing cannot be provided. Cycle networks should be planned and designed to facilitate direct crossing of arterial roads that are also bus routes rather than dog-leg crossings. Bus schedules should be include intermediate timing points, for the benefit of passengers as well as cyclists.
Bus Driver and Cyclist Attitudes and Behaviour	Bus drivers are trained for their job and spend a large amount of time on the road. Cyclists can feel unsafe in close proximity to buses, especially when the bus is driven too close or too fast for comfort. Uncaring or unknowing behaviour by drivers towards cyclists adversely affects cyclist safety. Irresponsible or unpredictable behaviour by cyclists adversely affects their own safety and creates hostility from other road users, including bus drivers.	Provision of adequate and, where possible, differentiated, space for buses and bicycles, will reduce the perceived conflict and is also more forgiving of error. If this is the approach, bus drivers will be less likely to be aggressive towards cyclists where the space available prevents the bus from overtaking the cyclist safely and conveniently. Differentiation of bus and bicycle networks reduces the likelihood of a bus being held up by a cyclist. Nevertheless, bus driver training should include specific attention to sharing the road, including bus lanes, with cyclists. Issues to be addressed include: • Where to expect cyclists on the road • Conspicuity of cyclists – looking for 'small' objects not just motor vehicles • Speeds of cyclists, at a point and over a length of road. It is also important that cyclists are aware of how to behave when sharing space with buses, including getting out of the traffic stream temporarily to allow buses to pass and riding in single file to maximise opportunities for buses to pass.
Young or Inexperienced Cyclists	Young or inexperienced cyclists are least able to cope with complex traffic situations. They may travel more slowly, be less predictable than experienced cyclists and unsettled by proximity of large and/or fast vehicles. They are more at risk of conflict with other road users and more likely to be seen as an impediment to buses.	Local cycle routes should avoid arterial roads and concentrations of buses or other heavy vehicles. Where this cannot be achieved, visually- or physically-separated facilities should be provided wherever possible. Where local cycle routes cross bus routes, particular attention should be paid to sight lines (for both bus drivers and for cyclists) and to signage to advise bus drivers of the likely presence of cyclists crossing. Bus stops should not be located where the presence of a bus would restrict the cyclist's ability to see motor vehicles that may overtake the stopped bus (ie on the upstream side of the intersection).
Bus Rear View Mirrors	External rear view mirrors on buses may be at cyclists' head height. This may pose a hazard for cyclists when	Bus driver training should ensure that drivers are aware of the need to look out for overtaking cyclists, especially when initiating a lateral movement in the roadway, and of the speed at which cyclists may approach and overtake.

Issue	Outline	Recommended Approach
	operating in close proximity to buses.	Cyclists should be made more aware of the importance of forward conspicuity, especially when the bus driver's only view of the cyclist may be through a rear vision mirror.
Bus Exhaust Fumes	Poorly-maintained buses may emit large quantities of exhaust emissions, especially particulates, in stop-start operation including where cyclists may be required to wait behind a bus (at signals or bus stops) because no passing opportunities are available.	Network planning and facility design can reduce the extent to which cyclists are forced to wait behind stopped buses. This may include enhanced bus priority at traffic signals. Bus operators should progressively adopt Euro 4 emission standards for new buses and carry out regular emissions checks on all buses. Cleaner fuels, such as natural gas, should be introduced where it is economic to do so. The location of bus exhausts should, wherever possible, be away from the kerbside.
Bicycle Storage Facilities	Bicycle storage facilities are a key element in fostering a complementary relationship between cycling and public transport, to the benefit of both. There are few examples of secure bicycle parking at regular bus stops.	Identify bus stops that meet the following criteria to provide bicycle parking: • A high proportion of longer-distance bus journeys • A bicycle catchment that is not served by adequate alternative public transport access with secure bicycle parking • Active or passive surveillance for security of parked bicycles.

Conclusions

The interaction between buses and bicycles within the road network has been neglected as a specific issue. Nevertheless, it is important for both cyclists and bus operators and users and failure to ameliorate adverse interactions as well as build on beneficial ones will be detrimental to both modes. The Toolkit available on the website of the Australian Bicycle Council (http://www.abc.dotars.gov.au) provides comprehensive guidance for addressing such interactions.

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References

AA (1993). *Cycling Motorists: how to encourage them*. Automobile Association: Basingstoke, England.

ACT (1997). *Canberra Bicycle 2000: A Bicycle Strategy for the Australian Capital Territory*. ACT Government: Canberra, ACT. http://www.actpla.act.gov.au/plandev/other_planning/cycling/index.htm

ATSB (2001). *Australian Bus Safety*. Australian Transport Safety Bureau, Department of Transport and Regional Services: Canberra, ACT. http://www.atsb.gov.au/road/stats/pdf/bus_travel.pdf

ATSB (2003). *Crashes involving seriously or fatally injured cyclists and a bus: Australia 1989 to 1996*. E-mail communication from Thomas Roberts, 8 December 2003. Australian Transport Safety Bureau: Canberra, ACT.

Austroads (1999a). *Australia Cycling: The National Strategy*. Austroads: Sydney, NSW. http://www.abc.dotars.gov.au/auscycling.pdf

Austroads (1999b). Guide to Traffic Engineering Practice: Part 14 – Bicycles. Austroads: Sydney, NSW.

Basford, L, Reid, S, Lester, T, Thomson, J and Tolmie, A (2002). *Drivers' perceptions of cyclists*. Report TRL549, TRL Limited: Crowthorne, Berkshire, England. ISSN 0968-4107. Report produced for Department for Transport. http://www.trl.co.uk/static/dtlr/cycling/TRL549.pdf

BFA (1997a). *Bicycles on Public Transport*. Policy 1997:2, Bicycle Federation of Australia: Canberra, ACT. http://www.bfa.asn.au/bfanew/policies/policy_bicycles_on_public_transport.htm

BFA (1997b). *Bicycles on Roads*. Policy 1997:5, Bicycle Federation of Australia: Canberra, ACT. http://www.bfa.asn.au/bfanew/policies/policy_bicycles_on_roads.htm

Bicycle Victoria (2003). *Bicycle Victoria Submission to Implementation Plan No. 6 – Integrated Transport*. Bicycle Victoria: Melbourne, Victoria. http://www.bv.com.au/download/melbourne_2030_submission_imp_plan_6.pdf

Brisbane (2003). *Transport Plan for Brisbane, 2002-2016*. Brisbane City Council: Brisbane, Queensland. http://www.brisbane.qld.gov.au/_downloads/transport_plan_full_document.pdf

CCC (2001-2003). *Newsletters: 38, 43, 45, 49, 50 and 51*. Cambridge Cycling Campaign: Cambridge, England. http://www.camcycle.org.uk/newsletters/previous.html

DoT (1996). *The National Cycling Strategy*. Department of Transport: London, England. http://www.dft.gov.uk/stellent/groups/dft_localtrans/documents/page/dft_localtrans_503877.hcsp

DTO (1997). *Provision of Cycle Facilities: National Manual for Urban Areas*. Dublin Transportation Office: Dublin, Ireland. http://www.dto.ie/publicdown.htm

FTA (undated – accessed 27 November 2003). *Bicycles and Transit: A Partnership that Works*. Federal Transit Administration, Department of Transportation: Washington DC, USA. http://www.fta.dot.gov/library/policy/bikes.pdf

Hendrie, D, Kirov, C and Gibbs, S (1998). *Bicycle Crashes and Injuries in Western Australia*. Report RR60, Road Accident Prevention Research Unit, Department of Public Health, University of Western Australia: Perth, WA.

Hendrie, D, Kirov, C and Gibbs, S (2000). *The Western Australian Bicycle Crash Study*. Report RR57, Road Accident Prevention Research Unit, Department of Public Health, University of Western Australia: Perth, WA.

MTS (1995). *Metropolitan Transport Strategy*. Department of Transport: Perth, Western Australia. http://www.dpi.wa.gov.au/metro/policies/pdfs/mts.pdf

National Cycling Strategy (1998). *National Cycling Forum: Cycling in Urban Areas – Issues for Public Transport Planners and Operators*. Department of Environment, Transport and Regions: London, England.

New Zealand (2003). *Getting There on Foot by Cycle: A draft strategy to increase walking and cycling in New Zealand Transport*. Government of New Zealand: Wellington, New Zealand. http://www.transport.govt.nz/business/land/getting-there/walk-cycle-strategy-071003.doc

Queensland Transport (2003a). *Queensland Cycle Strategy*. Brisbane, Queensland.

Queensland Transport (2003b). *Integrated Regional Cycle Network Plan for South East Queensland*. Brisbane, Queensland.

RTA NSW (1999). *Action for Bikes: Bikeplan 2010, New South Wales*. Roads and Traffic Authority: Sydney, New South Wales. http://www.rta.nsw.gov.au/roadsafety/downloads/freeresource/bp2010.pdf

RTA NSW (2003). NSW Bicycle Guidelines Roads and Traffic Authority: Sydney, New South Wales. www.rta.nsw.gov.au/trafficinformation/guidelines/documentregister/technicalmanuals.htm

South Australia (2003). *South Australia's Draft Transport Plan: Towards a sustainable transport future*. Adelaide, South Australia. http://www.dtup.sa.gov.au/transport_plan/index.html

Sydney (2003). *Central Sydney Bikeplan, 2003-2006*. City of Sydney: Sydney, NSW. http://www.cityofsydney.nsw.gov.au/pdf/attachment-central-sydney-bike-plan.pdf

TfL (2001). *The Mayor's Transport Strategy for London*. Greater London Authority: London, England. http://www.london.gov.uk/mayor/strategies/transport/index.jsp

Transport WA (1996a). *Bike Ahead: Bicycle Strategy for the 21st Century*. Department of Transport: Perth, Western Australia. http://www.dpi.wa.gov.au/cycling/documents/bike_ahead.pdf

Transport WA (1996b). *Perth Bicycle Network Plan*. Department of Transport: Perth, Western Australia. http://www.dpi.wa.gov.au/cycling/information/publications/documents/PBNP.pdf

Transport WA (1996b). *Better Public Transport: Ten-Year Plan for Transperth 1998-2007*. Department of Transport: Perth, Western Australia. http://www.dpi.wa.gov.au/publications/tenyearplan/home.html