Bike Racks on the Front of Buses:

Engineering and Road Safety Issues

Prepared by

Michael Paine

Vehicle Design and Research Pty Limited

for

Road Use Management

ACT Department of Urban Services

October 1997

CONTENTS

Disclaimer

The views expressed in this report are those of the author and do not necessarily represent the views of the ACT Department of Urban Services.

Introduction

This report sets out the results of a brief investigation into the engineering and safety issues associated with the use of bike racks on the front of transit buses.

In accordance with ACT Government policy (ACT 1997), the ACT government bus authority ACTION proposes to conduct "a trial of bike racks on express buses to encourage cyclists to use the bus systems as part of their journey". This is part of the strategy aimed at increasing "the proportion of commuter trips by cycling from 3% in 1997 to 6% by 2007".

The bike rack under consideration is manufactured by Sportworks NW in the USA. It attaches to the front of the bus and has space for carriage of two bicycles. When not in use it can be folded up against the front of the bus.

The engineering and safety issues which need to be considered are:

- Pedestrian safety: will the rack and/or bicycles at the front of the bus introduce an undue hazard to pedestrians?
- Bus turning and manoeuvring capability: will the extra projection at the front of the bus cause an undue increase in the road space required by the bus during turning or lane-change (entering or leaving the bus stop) manoeuvres? Will the ground clearance at the front be adequate to clear obstacles?
- Road space required at bus stops: will the extra length of the bus cause problems at bus stops, particularly if several buses are lined up?
- Driver visibility: will the rack and/or bike unduly interfere with the bus driver's view of the roadway?
- Visibility of lights: will the rack and/or bikes obscure the view, by other road users, of the mandatory lights at the front of the bus or the reduce the effectiveness of the bus headlights?
- Cognitive load on the driver: will the extra responsibility of observing the loading and unloading of bicycles place an undue demand on the bus driver? If the cyclist forgets to stow the rack after taking the last bicycle out of the rack, will the driver be expected to get out of the bus and do this?
- Global road safety effects: if the provision of bike racks on the front of buses does encourage greater use of bicycles, what are likely to be the overall road safety effects of this trend?

Other technical issues which are not within the brief for this project include the structural adequacy of the rack and its method of attachment to the bus; the influence of the rack on maintenance and cleaning of the bus and potential damage to bicycles carried by the rack. Another possible issue is the effect of delays at the bus stop. It is assumed that ACTION will take these issues into consideration in the design of the trial.

Research on bike racks on buses

A search of recent literature databases failed to find any research reports on this subject. A search of the World Wide Web found references to the use of bike racks on buses by three North American transit authorities: Toronto Transit Commission, Santa Cruz Metropolitan Transport District and County of Tomkins (New York).

The following email was received from the County of Tomkins:

Subject: FW: (Fwd) bike racks on buses

From: Dwight Mengel <dem11@cornell.edu>

To: "'mpaine@tpgi.com.au'" <mpaine@tpgi.com.au>

Dear Mr. Paine,

We installed Sportworks bike racks on all of our buses (42) last August. We were the first transit system in New York State to install bike racks fleet-wide, although Sportworks has about 5,000 bikes in use.

Simply, the bike racks are a success. The racks are front-mounted, hold two bikes, and load/unload in 10 seconds. They are very popular. We use them year round, including winter.

Half of the bus operators initially opposed the project. Their objections were based on concerns for time delay at the stop, safety (will the bikes fall off?), a perception of increase hazard, and resistance to change. We canvassed other systems. They told us their operators had the same questions but they were all resolved successfully. The bike racks are not a problem.

Loading & unloading by passengers is fast, the bikes do not fall off, the racks do not increase the turning radius of the bus, and passengers tell the drivers what a great idea the racks are.

The racks cost us $524 US in 1996.

I've attached a photo. (see cover)

Good luck,

Dwight Mengel

Project Manager

TCAT

Bike racks are also under consideration for transit buses in Perth and Adelaide. Mr Robert Broad is the project manager for TransAdelaide. During a telephone conversation he indicated that he was looking at a wide range of issues, including safety. He has been advised by Sportworks in the USA that they have over 10,000 bike racks fitted to the front of buses in the USA, involving more than 140 bus companies. They have had no product liability insurance claims in the USA arising from incidents involving the bike rack (evidently this is very unusual for any vehicle accessory) and are not aware of any safety problems with the rack. Mr Broad said that the SA Department of Transport has a "bull bar" committee which will be looking at the bike rack issue.

Mr Broad confirmed that rear mounted racks had been considered but the driver did not have a clear view of the loading and unloading of bikes and this caused unnecessary danger to the cyclist. Also it is more difficult to judge clearance when reversing.

He said that more care was needed when drivers negotiated some of the tight streets in Adelaide. They were also checking whether there was a potential visibility problem with short stature drivers. Bus workshop practices needed to be reviewed to avoid hazards from the presence of the rack (mainly people walking into it when moving around the front of the bus).

The author had a brief discussion with the NSW representative on the Australian Motor Vehicle Certification Board who recalled the issue being briefly discussed a few years ago, after being raised by the West Australian representative. He recalled that there was unanimous objection to the proposal for front-mounted bike racks on buses, due mainly to the increased hazard to pedestrians. It appears, however, that this issue was treated relatively informally by the Board.

It is understood that bike racks are fitted to the front of transit buses in some European cities.

Design of the Sportworks bike rack

The design of the bike rack is illustrated in the following diagram. It has two positions: stowed and deployed. In the deployed position it extends 690mm ahead of the bumper bar of the bus. In the stowed position it extends approximately 200mm ahead of the front panel of the bus. It is centrally mounted and its width is just under 1.7m - the typical length of an adult bicycle. Since the typical bus width in Australia is the legal limit of 2.5m, the transverse distance between the end of the rack and the side of the bus is about 400mm.

The frame of the bike rack is made from steel tubing. All contactable edges appear to be well rounded.

Pictures courtesy of SCMTD (see Appendix A)

Loading and unloading of bicycles is very simple, and this is probably a reason for the apparent popularity of the Sportworks rack in North America. The bicycle wheels fit into slots formed by the frame of the rack. A support arm then swings over the top of the front tyre and is spring loaded so that it lightly clamps onto the tyre. In this way the only contact between the rack and the bicycle is through the bicycle tyres.

The rack can be stowed and deployed by the cyclist using one hand. No assistance is required from the driver or any other person.

From the pictures and the description of the Sportworks rack this appears to be an entirely suitable technical design for the purpose of carriage of bicycles at the front of the bus. Dislodgment of the bicycle during transit is highly unlikely, provided that the cyclist remembers to swing the support arm into place.

Pedestrian safety

Mechanisms of pedestrian injury

The risk of injury to pedestrians can arise in three main ways. Firstly during a substantial collision between the bus and a pedestrian the design of the front of the bus can influence the direct injuries due to contact between person and the bus components. Secondly, during a substantial collision between the bus and a pedestrian the design of the front of the bus can influence the indirect injuries through the resulting motion of the pedestrian - in particular head impacts with the pavement. Thirdly, during a low speed incident, or when the bus is stationary, the pedestrian might get caught by components attached to the bus.

Australian Design Rule 42/03 (ADR 42), Clause 12 requires that no vehicle must be equipped with:

- any object or fitting, not technically essential to such vehicle, which protrudes from any part of the vehicle so that it is likely to increase the risk of bodily injury to any person
- any object or fitting technically essential to such vehicle unless by its design, construction and conditions and the manner in which it is affixed to the vehicle are such as to reduce to a minimum the risk of bodily injury to any person
- any object or fitting which, because it is pointed or has a sharp edge, is likely to increase the risk of bodily injury to any person; or
- any bumper bar the end of which is not turned towards the body of the vehicle to a sufficient extent to avoid any risk of hooking or grazing.

Similar requirements apply to the loading of vehicles under the Mass and Loading Regulations, and associated Load Restraint Guide, issued by the National Road Transport Commission. These requirements would apply to the carriage of a bicycle on the outside of a bus.

Compared with the relatively flat surface of the front of the bus, it is considered the bike rack, in either the deployed or stowed position, does increase the risk of bodily injury to pedestrians. The risk is likely to be increased when the rack is carrying a bicycle, due to the numerous projecting components on a bicycle. On the other hand, the rack, and particularly a bike mounted on the rack, could yield under high impact loads. Therefore in some severe types of collisions it is possible that a bike rack and bicycle might provide a cushioning effect which could reduce the severity of the collision. Such cases are likely to be very rare.

On balance, it is considered that the bike rack slightly increases the risk of injury to pedestrians and therefore the clauses of ADR42 are considered applicable. The questions arising from the ADR42 requirements are:

1. Is the bike rack technically essential? Yes - it does have a functional purpose related to the operation of the bus.
2. Is the risk minimised? Qualified yes - given the technical constraints on the design of the bike rack it is considered that it is an optimum design for the purpose. It is possible that additional tubes and/or padding could be added to reduce the risk of direct injury, due to impact, or being caught by the device. However, these would add to the complexity and weight of the device and probably increase the need for maintenance.
3. Have pointed or sharp objects been avoided? Qualified yes - as for item 2. In the case when the device is carrying a bicycle a cover or other device could be added to shield the pedestrian from contact with the bicycle but this would add significantly to the complexity of the device.
4. Has the risk of hooking or grazing been avoided? Yes - as for items 2 and 3.

Overall, it is considered that the design of the bike rack meets the intention of clause 12 of ADR42. It is noted that the concerns about the bike rack are similar to those raised about bull bars. It is understood that policy on bull bars is under review in several Australian jurisdictions and this could have implications for policy on bike racks.

Statistics on pedestrian accidents

In considering the issue of injury to pedestrians it is appropriate to take into account relevant accident statistics involving pedestrians.

No direct research information could be located about the risk of a pedestrian being hit by the front of a bus.

McFadden (1996) reported that out of 303 pedestrian fatalities recorded in 1992 a total of 7 (2.3%) involved a bus. It is likely that most of these involved the front of the bus hitting the pedestrian, although sufficient details are not available to support this assumption. However, US data indicates that about two-thirds of pedestrian injuries involve the front of the vehicle (NHTSA 1996).

The NSW RTA, in a report "Safety of school children near buses" (RTA 1992), set out child pedestrian casualities involving school buses (that is, the bus was directly involved in, or was in the vicinity of, the accident):

Type of accident	Killed	Serious Injury	Other Injury	Total
Hit by front of bus	1	2	6	9
All accidents	5	38	64	107
Percentage of all accidents	20%	5%	9%	8%

Note that most of the casualties arose from the child emerging from the front or rear of the bus into the path of a passing vehicle. Given that in all these cases there was at least a bus in the vicinity of the incident then the overall casualties suggest that being hit by the front of a bus is a rare event in the school bus situation. Note the very small sample size in the case of fatal accidents therefore the derived proportion is not statistically meaningful.

During 1993 in NSW, out of 793 fatal accidents (of all types, not just pedestrians), a total of 14 (1.8%) involved a bus. Out of a total of 3208 pedestrian casualties 117 (3.6%) were killed. This is approximately double the fatality rate for non-pedestrians (i.e drivers, riders and passengers) and indicates that a pedestrian accident is more likely to be fatal than most other types of *reported* road accidents. For comparison, there were a total of 1,451 pedal cycle rider casualties including 8 fatalities (0.6%).

Effect of bike racks on pedestrian accidents

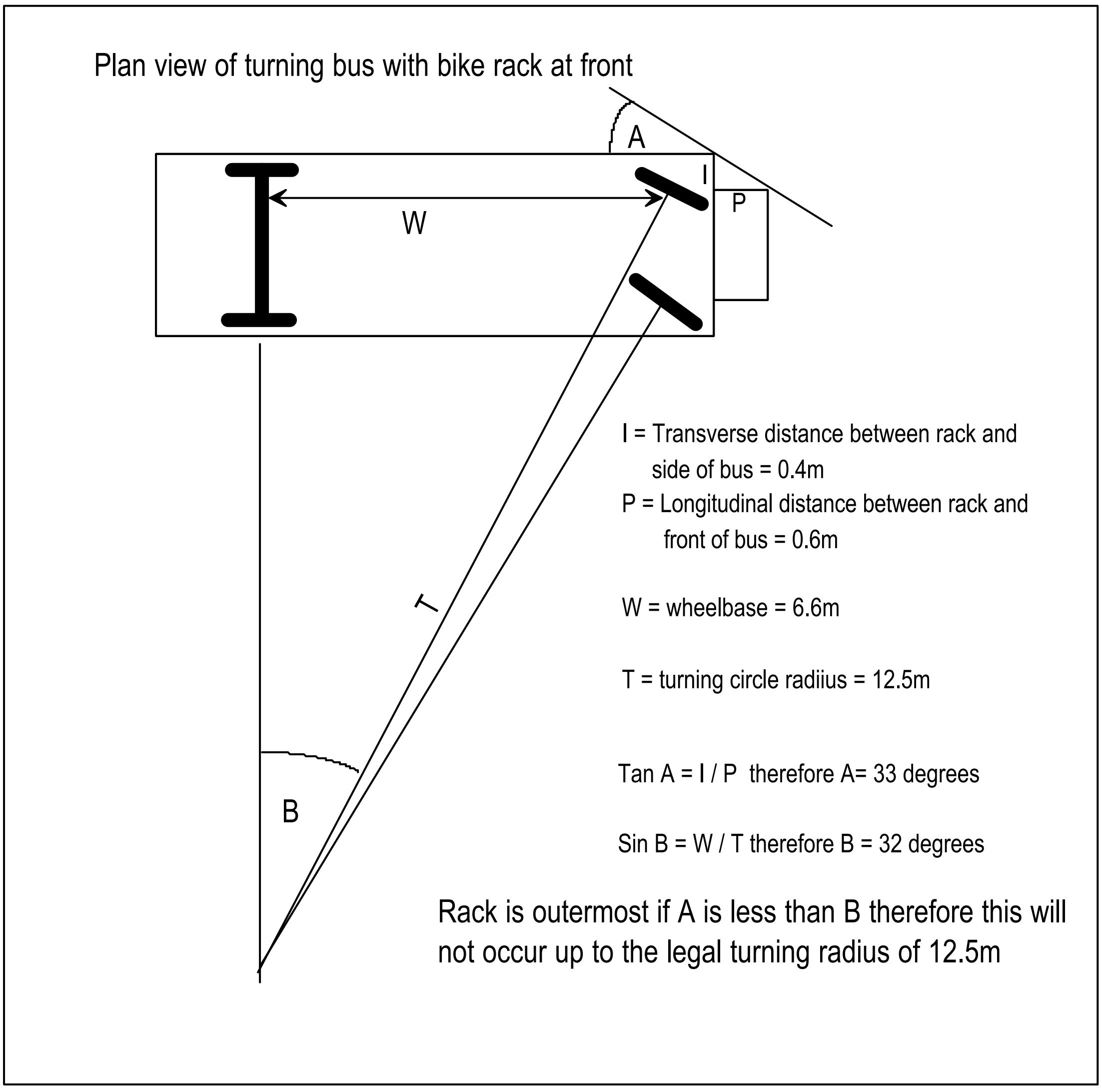
In summary, it is not possible to reliably estimate the possible effects of bus-mounted bike racks on pedestrian accidents due to a lack of data about pedestrian/bus accidents. There is no reason to believe that the *number* of accidents involving a pedestrian being "hit" by the front of a bus would increase due to the presence of a bike rack (there might, however, be incidents where the cyclist is caught while loading or unloading while the bus is stationary or moving at a very low speed). There is a slight risk that the *severity* of moderate to high speed collisions between pedestrians and buses would increase slightly, due to the extra projections at the front of the bus but some types of impacts could be mitigated by deformation of the rack and bicycle.

Buses are involved in only a small proportion of all *fatal* pedestrian accidents and are likely to have a similar low direct involvement in all types of pedestrian accidents. Therefore it is expected that any change in the number of serious bus/pedestrian accidents arising from widespread use of bike racks on the front of buses will be negligible, particularly when compared with the overall number of pedestrian accidents or the overall road accident casualties.

Bus turning and ground clearance

During a turning or lane change manoeuvre the outside front corner of the bus normally defines outer limit of the "swept path" and is the point most likely to collide with other objects. The front corner of the bike rack is some 600mm forward of this point but is also about 400 inboard from the side of the vehicle. This means that it will only become the outer limit of the swept path above certain angles of steering lock. This can be calculated from a simplified analysis of the turning bus, as illustrated in the diagram overleaf.

Dimensions are based, in part, on the ACTION specification for rigid route buses (ACTION 1991) and estimates of the installed dimensions of the bike rack. These should be confirmed by actual measurements of a trial bus.



Based on the available data, it is expected that the presence of the bike rack will not increase the size of the swept path down to the tightest turning radius specified in ADR 43 (12.5m to the outer front tyre or 25m "kerb to kerb").

In accordance with ADR 43, the ground clearance must be sufficient to enable the bus to negotiate a ramp angle of 7 degrees 38 minutes. Assuming that the bike rack is 0.5m above the ground and 3m forward of the front axle of the bus then the resulting angle from the tyre contact point to the front of the bike rack is 9 degrees 30 minutes. Based on these assumptions, the ground clearance complies with ADR 43.

Length of bus

Assuming that ACTION now specifies buses up to the maximum length of 12.5m permitted under ADR 43 then the bike rack will exceed the length limit by about 600mm in the deployed position and between 100 to 200mm in the stowed position. This could have implications for the space taken up by buses at bus stops, particularly if several buses fitted with deployed bike racks need to use the same bus stop. There simply might not be enough space to accommodate these buses. On the other hand, this situation is no different to the case where too many buses arrive at the bus stop at the same time.

If the bus exceeds statutory length limits then a permit would be required from the registration authority. If the use of bike racks becomes widespread then this would be best achieved under the "notice system" being promoted by the National Road Transport Commission so that the need for individual vehicle permits is avoided..

Driver visibility

It is unlikely that the presence of a bicycle on a bike rack would interfere with driver vision to the extent that it encroaches on the primary vision area. In effect, ADR 8 requires the driver to be able to see a point on the road surface 11m ahead of his/her eye position. Assuming that the driver's eye position is 2m above the roadway then this corresponds to a viewing angle of 10 degrees below the horizontal. Assuming the driver's eye position is 1m rearward of the front of the vehicle and the top of the bicycle is 1.3m above the road surface and 0.6m ahead of the front of the bus, then the corresponding viewing angle is 23 degrees below the horizontal. On the basis of these assumptions, the bicycle will be well below the primary vision area specified in the ADR.

Visibility of lights

ADR 6 requires the front turn signals to be visible over a range extending from 80 degrees outboard to 45 degrees inboard. The calculation made for swept path determination suggest that the angle between the front corner of the bus and the outer front part of the bike rack/ bicycle combination will be 33 degrees inboard. Therefore, when is use, the bike rack is likely to obscure the front turn signals to the extent that they would not comply with ADR 6. This is evident in a newspaper photograph of the bike rack being demonstrated on an ACTION bus. Consideration should therefore be given to the fitting of supplementary turn signal lamps at the front of the bus.

From the same photograph it appears that the bike rack does not obscure the bus headlights.

Occupant protection issues

The presence of a bike rack on the front of the bus is unlikely to have any deleterious effects on bus occupants in the event of a crash.

In the case of other vehicles being struck by a bus, the presence of a bike rack is unlikely to have an effect (unlike bull bars which are generally stiffer than the vehicle being struck). Vulnerable road users such as bicycle riders and motorcyclists might be exposed to slightly higher risk of injury in the same manner as pedestrians.

Cognitive burden on the driver

During 1996 the author was involved in the assessment of a crossing control arm, proposed for the front of school buses in NSW to discourage children from crossing at the front of the bus. One of the concerns about this device was the extra cognitive burden on the bus driver. Bus driving in general and pulling out of bus stops in particular, is recognised as a demanding task and extra responsibilities at this time should be avoided. The presence of a bike rack would not place as great a demand on the driver as the proposed crossing control, which had to retract fully before the bus drove off (with a consequence risk of children waiting on the footpath instinctively stepping out into the path of the bus when the barrier retracted). However, it would be appropriate to train drivers for the extra tasks involved in use of bike racks.

Incidentally, one of the main factors which resulted in cancellation of the trial of the crossing control arm in NSW, and a strong recommendation against its use, was that no children were observed attempting to cross the road at the front of the bus during extensive video monitoring of a bus without a crossing control arm. Therefore there could be no measurable benefit from fitting a crossing control arm. Evidently student pedestrians rarely walk near the front of a bus - this observation has implications for the assessment of the bike rack .

Overall community effects

There are indirect community benefits arising from the joint encouragement of bicycling and busing (based on Canberra Bicycle 2000)

- Reduced peak period traffic congestion
- Reduced demand for new/upgraded roads and parking spaces
- Reduced greenhouse gas emissions and reduced dependence on fossil fuels
- Reduced air pollution from vehicles
- Improved community health due to reduced air pollution and the healthier lifestyle of cyclists ("20 times as many life years are gained through improved health as are lost because of accidents")

Provided that adequate traffic facilities are available for cyclists then an overall reduction in serious road accidents could be expected from a move away from cars and towards buses and bicycles (as indicated previously, NSW cyclists have a lower injury severity rate than most other road users).

Conclusions

The use of bike racks on the front of buses is likely to result in a slight increase in the risk of injury to pedestrians in the event that they are hit by the front of a bus. However, incidents of pedestrians being hit by the front of a bus are apparently very rare - a Federal study found that 2.3% of pedestrian fatalities recorded in Australia during 1992 involved a bus and it is likely that not all of these involved the pedestrian being hit by the front of the bus. In other words, there may be a slight increase in the risk of injury during a very rare event and the overall effects on road safety are considered to be negligible.

There are several environmental, economic and health benefits to the community arising from the encouragement of cycling and/or commuting by bus. These include possible road safety benefits (arising mainly from reduced use of cars) which could more than offset the extra risk to pedestrians.

Operational issues which need to be addressed to minimise road safety problems are:

- driver training for driving a bus fitted with the racks;

- instructions to cyclists about the use of the racks (see Appendix A);
- identification of bus stops which are unsuitable for loading and unloading bicycles (see Appendix A);
- the possible need for supplementary turn signals and
- issue of overlength permits, if required.

References

ACT (1997) "Canberra Bicycle 2000", ACT Government July 1997 (from Pedalpower web site - see below).

ACTION (1991) "Request for tender for the supply and delivery of rigid route buses", ACTION (ACT Buses) Specification TS/7/91 August 1991.

Adams A and Paine M, (1996) "The school bus crossing control arm: an evaluation", Consultants report to NSW Bus Safety Advisory Committee, December 1996 (available from Transport Safety Bureau, NSW Department of Transport).

Fisher A and Hall R, (1972) "The influence of car frontal design on pedestrian trauma", *Journal of Accident Analysis and Prevention,* 4, 47-58.

FORS (1997) "Australian Design Rules for Motor Vehicles", CD ROM verison, 1997.

Haley J (1994) "Pedestrian friendly vehicle design", *Proceedings of Bull bar Safety Workshop,* RTA NSW May 1994.

McFadden M, (1996) "Pedestrian safety", *Proceeedings of 15th Conference on the Enhanced Safety of Vehicles (ESV)*, Melbourne 1996.

McLean AJ (1994) "Head injury, mechanism and mitigation", *Proceedings of Bull bar Safety Workshop,* RTA NSW May 1994.

NHTSA (1996) *Traffic Safety Facts 1995,* National Highway Traffic Safety Administration, Washington.

Paine M and Fisher A (1996) "Flashing warning lights for school buses", *Proceeedings of 15th Conference on the Enhanced Safety of Vehicles (ESV)*, Melbourne 1996 (see http://www1.tpgi.com.au/users/mpaine/buslight.html).

Pedalpower (1997) "Bikes and buses", *Canberra Cyclist,* Issue No.137, July August 1997 (http://sunsite.anu.edu.au/community/pedalpower).

Reilly-Jones C and Griffiths M, (1996) "The effects of bull bars on pedestrian injury mechanisms and kinematics", *Proceeedings of 15th Conference on the Enhanced Safety of Vehicles (ESV)*, Melbourne 1996.

RTA (1992) "Safety of school children near buses", report of School Bus Safety task Force, NSW Roads and Traffic Authority, May 1992 (the author was a member of the Task Force).

SCMTD (1997) "SCMTD Bike Rack Program", Santa Cruz Metropolitan Transport District, California, WWW page http://www.scmtd.com/changes/bikerack.html.

Sportworks (1994) "DL2 Bicycle rack for buses specifications", Sportworks NW, USA, December 1994.

TCAT (1996) "Transit bus front mounted bicycle racks", resolution of Tomkins County, New York, Board of Representatives, 7th February 1996 (http://www.co.tomkins.ny.us/bor/96resolutions/r025-96.html)

Tomas J (1994) "Bull bars and road users", *Proceedings of Bull bar Safety Workshop,* RTA NSW May 1994.

TTC (1997) "Bicycle racks for buses", Minutes of a meeting of the Planning and Transportation Committee, Toronto Transit Commission, Canada, April 25, 1997 (http://www.meteor.on.ca/services...)

About the author

Michael Paine is a professional mechanical engineer with over 20 years experience in road safety - particularly in the development of vehicle construction standards.

He has conducted or contributed to several projects involving buses and pedestrian safety:

- On-site technical adviser to the Ministers for Transport and Police on the day of the Grafton bus crash in 1989. Initiation of various safety issues resulting from assessment of that crash.
- Member of the School Bus Safety Task Force, Roads and Traffic Authority of NSW which produced the report "Safety of School Children Near Buses" May 1992. Survey of Australian states and territories, evaluation of radar pedestrian detectors and other devices, analysis of sight and stopping distances, need for flashing lights on the *front* and rear of buses.
- "School Bus Seat Belts". Research report for NSW Department of Transport, 1994 (joint authorship with Dr Michael Henderson). Statistics on school bus travel and composition of bus fleet, analysis of accident reports, technical issues about fitting seat belts to buses, cost effectiveness analysis.
- "Australian Bus Safety Standards" & "Australian Bus Accidents (1970-92)". Research reports prepared for National Road Transport Commission (NRTC), May 95. Survey of construction requirements applying in Australian states and territories, analysis of press reports and other bus accident data over a twenty two year period, estimation of the effects of various safety measures.
- "Evaluation of School Bus Signalling Systems". Research report for NSW Department of Transport, June 95 (joint authorship with Dr Alec Fisher). Evaluation of several types of signalling systems for use on school buses, analysis of sight distances, braking performance and required range of signal lights, field evaluation of the performance of signal lights, development of a specification for signal lights on school buses.
- "Flashing Warning Lights on School Buses". Proceedings of 15th International Conference on the Enhanced Safety of Vehicles, Melbourne May 1996 (joint

authorship with Dr Alec Fisher). Based on the research report, particularly visual ergonomics.

- "Speed Control Devices for Cars". Research report for Roads and Traffic Authority of NSW, June 1996 (publication pending). Review of devices to control vehicle speeds or improve speeding behaviour of drivers, relationship between speed and crash involvement, relationship between speed and crash severity, estimates of crash savings from reducing vehicle speeds, costs and benefits of various safety measures.
- "The School Bus Crossing Control Arm - an Evaluation". Research report prepared for Department of Transport NSW and NSW Bus Safety Advisory Committee, December 1996 (joint authorship with Dr Austin Adams). Defining the intended purpose of a boom arm for use in NSW (to discourage children from crossing near the front of the bus), development of technical specifications for a boom arm, on-road collection of data about the road crossing behaviour of children on a bus without a boom arm, off-road evaluation of the effects of a boom arm on crossing behaviour.
- Assisting the RTA of NSW in the development of specifications for devices to reduce the risk of entrapment in bus doors. Assisting the NRTC in the preparation of national vehicle standards on this issue.
- Assisting in the development of NRMA policy on bull bars - unpublished work for NRMA Vehicles and Environment , May 1997.
- Preparation of national administrative guidelines for dealing with oversize and overmass vehicles, including overlength buses. Documents prepared for the NRTC (draft dated October 1997 about to be circulated).

Appendix A - Santa Cruz Metropolitan Transit Web Site

The following pages are from the World Wide Web site of the Santa Cruz Metropolitan Transit District: http://www.scmtd.com/changes/bikerack.html