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TRAFFIC FLOW MODELS ALLOWING FOR PEDESTRIANS AND CYCLISTS

AUSTROADS

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AUSTROADS

Sydney 2001

AUSTROADS PROFILE

Austroads is the association of Australian and New Zealand road transport and traffic authorities whose purpose is to contribute to the achievement of improved Australian and New Zealand transport related outcomes by:

- developing and promoting best practice for the safe and effective management and use of the road system
- providing professional support and advice to member organisations and national and international bodies
- acting as a common vehicle for national and international action
- fulfilling the role of the Australian Transport Council's Road Modal Group
- undertaking performance assessment and development of Australian and New Zealand standards
- developing and managing the National Strategic Research Program for roads and their use.

Within this ambit, Austroads aims to provide strategic direction for the integrated development, management and operation of the Australian and New Zealand road system — through the promotion of national uniformity and harmony, elimination of unnecessary duplication, and the identification and application of world best practice.

AUSTROADS MEMBERSHIP

Austroads membership comprises the six State and two Territory road transport and traffic authorities and the Commonwealth Department of Transport and Regional Services in Australia, the Australian Local Government Association and Transit New Zealand. It is governed by a council consisting of the chief executive officer (or an alternative senior executive officer) of each of its eleven member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Main Roads Queensland
- Main Roads Western Australia
- Transport South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Transport and Works Northern Territory
- Department of Urban Services Australian Capital Territory
- Commonwealth Department of Transport and Regional Services
- Australian Local Government Association
- Transit New Zealand

The success of Austroads is derived from the synergies of interest and participation of member organisations and others in the road industry.

Executive Summary

ARRB Transport Research was commissioned by Austroads to undertake a study of traffic flow models allowing for pedestrians and cyclists. This involved identifying models that consider pedestrians and cyclists and their relevance for use in Australia and New Zealand.

The first stage of the study involved a review of Australian, New Zealand and overseas literature to identify safety and mobility issues associated with pedestrians and cyclists and traffic management treatments. A number of issues were identified and are discussed. Also the level of coverage of pedestrians and cyclists in Austroads Guide to Traffic Engineering Practice Parts 9 – Arterial Road Traffic Management, 10 – Local Area Traffic Management, 13 – Pedestrians, and 14 – Bicycles was investigated.

The second stage of the project investigated traffic models that allow for pedestrian and cyclists. The type of models that were identified ranged from manually based models through to computer simulation models. A brief description of the models is provided in the text.

The method adopted for assessing pedestrian facilities in the current Austroads Guide to Traffic Engineering Practice Part 13 is the level of service criteria developed in the early 1970's by Fruin. It would seem that this criteria is still relevant as current models are based on Fruin's work and the theory is based on sound principles that continue to apply.

No tool to assess cycling facilities is included in current Austroads Guide to Traffic Engineering Practice Part 14. The review identified that there are a number of bicycle models that are useful tools for assessing both new and proposed bicycle facilities. These include methods based on level of service, capability, safety ranking and density.

It is recommended that the research findings from this study should be referenced when Parts 13 – Pedestrians, and 14 – Bicycles of the current Austroads Guide to Traffic Engineering Practice Series are reviewed.

Contents

1 Introduction

ARRB Transport Research was commissioned by Austroads to undertake a study of traffic flow models allowing for pedestrians and cyclists. This involved identifying models that consider pedestrians and cyclists and their relevance for use in Australia and New Zealand. The first stage of the study was to identify safety and mobility issues associated with pedestrians and cyclists and to investigate the coverage of pedestrians and cyclists in Austroads Guide to Traffic Engineering Practice Parts 9 – Arterial Road Traffic Management, 10 – Local Area Traffic Management, 13 – Pedestrians, and 14 – Bicycles. The second stage was the identification of traffic models that allow for pedestrian and cyclists. Taking on board the findings of this study, ARRB Transport Research have developed recommendations for future revision of the above mentioned Austroads Guidelines.

1.1 Background

In the past traditional traffic management has focused on motor vehicles with minimal consideration given to other road users such as pedestrians and cyclists. As a consequence pedestrians and cyclists can often experience mobility constraints and risks to their personal safety as a result of traffic management treatments.

The Austroads Strategy for Traffic Management emphasises the need to re-focus traffic management modelling and practices to the movement of people and goods, rather than the traditional focus on vehicle flow and vehicle delay. This has been the initiator of this particular study.

1.2 Objectives

The three main objectives of this particular project are listed below with the overall vision being that greater emphasis will be placed on pedestrians and cyclists in terms of mobility and safety when considering traffic management treatments. The three main objectives include:

1. To identify safety and mobility issues pertaining to pedestrians and cyclists with respect to traffic management treatments;
2. To determine what traffic flow models exist that consider pedestrians and cyclists and how applicable they are in the Australian and New Zealand context; and
3. To offer recommendations for consideration in future revisions of the Austroads Guide to Traffic Engineering Practice Series.

1.3 Scope of the Report

The first stage of the report outlines safety and mobility issues pertaining to pedestrians and cyclists using traffic management treatments identified through a review of literature. This section also discusses the types and characteristics of pedestrians and cyclists. Although some traffic management treatments are discussed, the intent of this part of the report is not to discuss the range of treatments that are available but rather to focus on the safety and mobility issues themselves.

The major part of the study was to determine traffic models developed for pedestrians and cyclists and how applicable they are in the Australian and New Zealand context. Although some traditional vehicle traffic flow models have elements that consider pedestrians and cyclists the focus of this study was on models that have been developed specifically for pedestrians and cyclists. A brief discussion of each model is provided. The scope of the discussion does not include economic assessment of pedestrian and cyclist facilities.

Finally, recommendations are provided for consideration when undertaking a review of the Austroads Guide to Traffic Engineering Practice Series.

2 Methodology

The following processes were undertaken as part of the study:

1. *Literature review*

   A review of the current relevant section of the Austroads *Guide to Traffic Engineering Practice Parts 9 – Arterial Road Traffic Management, 10 – Local Area Traffic Management, 13 – Pedestrians, and 14 – Bicycles* was undertaken to determine the level of coverage of pedestrians and cyclists in these documents.

   A review of Australian and overseas literature was carried out to identify the safety and mobility issues of pedestrians and cyclists in regards to traffic management treatments.

2. *Investigation of traffic models allowing for pedestrian and cyclists*

   Traffic models were identified that focussed on pedestrians or cyclists and a brief description of each is provided.

3. *Outcomes*

   Findings have been documented for consideration in future revision of Austroads Guide to Traffic Engineering Practices Series

3 Literature Review

3.1 Preamble

A literature review of relevant Austroads guidelines, eg the *Guide to Traffic Engineering Practice Series* and other Australian and overseas documents was undertaken. The main focus of the review centred on pedestrian and cyclist safety and mobility issues regarding traffic management treatments.

3.2 Types of Pedestrians and Cyclists

Pedestrians and cyclists are not a homogeneous group. Pedestrians can vary by age and capabilities. Gunnarsson (1995) has grouped pedestrians into the following categories in the Table 1.

ETSC (1999) states that, on average, pedestrian and cyclists crash risks are higher for children, young people and the elderly road users, with the risk of death in traffic for pedestrians aged over 65 being four times higher than for all younger age groups. Austroads (2000) also noted that there is an increase in pedestrian risk associated with being elderly, a child or affected by alcohol.

Pedestrians vary in their ability to move, read and interpret traffic signs, avoid obstacles, hear approaching vehicles, orientate themselves and to perceive risk.

Table 1: Classification of types of pedestrians

Age	Toddlers
	School children, Teenagers
	Adults and Elderly
Capacity	Full capacity
Type of handicap	Handicapped (physically, mentally)
Equipment used	Crutch, cane or walker
	Wheelchair or rollator
	Roller-skates, Skate boards
Occupation of hands	Hands free
	Guiding children, people with disabilities
	Carrying toys, shopping or luggage
	Pushing Pram, shopping trolley
	Walking an animal
Group Size	Single
	A couple or family
	Procession, parade

Source: Gunnarsson 1995

Cyclists are a diverse group of road users. They also vary in age and capabilities and have varying degrees of experience in cycling. Austroads Guide to Traffic Engineering Practice Part 14 (Austroads, 1999) has divided cyclists into seven broad groups namely, primary school children, secondary school children, recreational cyclists, commuter cyclists, utility cyclists, touring cyclists and sports cyclists in training.

Therefore, each of these groups has different needs when considering safety and mobility issues associated with traffic management treatments.

3.3 Characteristics of Pedestrians and Cyclists

Pedestrians and cyclists have specific characteristics, different from those of vehicles, which need to be considered to fully understand safety and mobility issues of pedestrians and cyclists. ETSC (1999) outlines the key aspects of pedestrians and cyclists in today's traffic system, namely:

- ***Vulnerability*** Even at relatively low impact speed, pedestrians and cyclists receive severe injuries. Speed plays an important role in determining the severity of the outcome of collisions. If the collision speed exceeds 45 km/h the likelihood for a pedestrian or cyclist to survive the crash is less than 50 per cent. If the collision speed is less than 30 km/h more than 90 per cent of those struck survive. Speed management, therefore, is a key element in a safe traffic system for vulnerable road users.
- ***Flexibility*** Pedestrians and cyclists are very flexible in their behaviour and flexibility is one of the main advantages of these modes. In relation to other road users, however, this presents a problem. A motor vehicle driver can never be sure when or where to expect a pedestrian or a cyclist.
- ***Instability*** A small mistake or a minor failure of the cycle may result in a severe outcome even though there are no other road users present. A pedestrian may stumble and receive serious injuries just because of an uneven surface. The instability of pedestrians and cyclists is an even bigger problem when they are mixed with motor traffic.
- ***Invisibility*** Pedestrians and cyclists can be difficult to see: They are small compared to a car, and can be hidden by one. At night the problem is more severe.
- ***Differing abilities*** Pedestrians and cyclists include children with lack of experience, elderly people with reduced capability and people with reduced mobility.
- ***Consciousness of effort*** Making a detour in a motor vehicle may use extra fuel, but for pedestrians and cyclists it means extra use of their muscles. They are therefore highly motivated to find and keep to the easiest routes, often the most direct ones.
- ***Estrangement*** Pedestrians are often focused on other things, like window shopping or chatting with friends while walking. This, together with the fact that the modern traffic environment is often designed for cars rather than for pedestrians and cyclists, creates a state of estrangement of pedestrians and cyclists.

3.4 Coverage of Pedestrians and Cyclists in Current Austroads Guidelines

The first stage of the literature review was to examine the Austroads guidelines to determine what extent pedestrians and cyclists have been considered.

Guide to Traffic Engineering Practice Part 9: Arterial Road Traffic Management

This document provides guidance on principles and practices associated with traffic management applicable to urban and rural arterial roads. The following points discuss the coverage of cyclist and pedestrians in each of three main sections of the document.

- *Traffic management*: This section addresses that **all** road users' needs should be considered in traffic management proposals, however, this is not filtered through the remainder of the document. This section also discusses traffic management strategies regarding traffic control devices, providing tables outlining the use of intersection and pedestrian control devices. There are no guidelines pertaining to the provision of facilities for cyclists.
- *Urban arterial roads*: Guidance is provided on the application of intersection controls with respect to vehicles and briefly to pedestrians (ie. crossing the intersection). Cyclists are not mentioned. When discussing mid-block applications, generally no emphasis is placed on pedestrians or cyclists. However, the provision of cyclist lanes on the kerbside of arterial roads are discussed and reference made to *NAASRA (1988) Planning and Design for Bicycles* on two occasions. Pedestrians are considered in the discussions on medians in relation to pedestrian refuges. The guidelines provide a section on pedestrian facilities regarding various crossing treatments, and suitable criteria for the use of such treatments.

Reference is made to AS1742.10 for further guidance, standards and warrants regarding the use of pedestrian facilities. There is a section discussing cyclist facilities. It is appreciated that the main function of an arterial road is to provide efficient and safe traffic movement. This is clearly covered in relation to vehicles, however, there needs to be an integrated approach with vehicles and other road users such as pedestrians and cyclists appropriately considered.

- *Rural arterial roads*: This section distinguishes the difference between urban and rural arterial roads ie. rural roads involve longer distances, higher speeds and there is a need for provision to overtake slower vehicles. Therefore, this section is focused on the provision of road treatments for intersections, safe overtaking procedures, speed management and quality of service improvements. Pedestrians and cyclists are mentioned occasionally. Reference is made to the urban arterial road section and other parts of the guide, which discuss pedestrians and cyclists.

Guide to Traffic Engineering Practice Part 10: Local Area Traffic Management

The document discusses the processes involved in Local Area Traffic Management (LATM) without focusing on either motorised vehicles or non-motorised road users such as pedestrians and cyclists. It considers the total effects of LATM treatments. The document promotes the need to consider the interaction of transport, land-use and the non-traffic community. Guidelines are provided to assist the reader when carrying out each individual process in LATM.

Guide to Traffic Engineering Practice Part 13: Pedestrians

The document provides standards for walkways and footpaths, types of pedestrian facilities for crossing roads, suggested signing and other guidance methods catering for the needs and capabilities of pedestrians. The guideline also outlines treatments applicable for public transport, work sites and parking areas.

Guide to Traffic Engineering Practice Part 14: Bicycles

The document provides a comprehensive guide to the facilities and treatments available to support the requirements of cyclists. The guide recommends various treatments in relation to types of bicycle facilities, the design of road/path intersections, traffic control devices, bicycle parking requirements, pavement design, provision of bicycle structures and ‘end of trip’ facilities.

It is acknowledged that the guidelines will always be behind practice if we are progressing in traffic design and management. However, from reviewing these guidelines cross-referencing between these documents needs to be developed to encourage provision of suitable facilities for pedestrians and cyclists. Although the development of traffic management tools is ongoing, Parts 13 and 14 offer a range of valuable treatments for consideration when addressing the requirements of pedestrians and cyclists. Cross-referencing of these options in other documents contained in the Austroads Guide to Traffic Engineering Series would prompt the practitioner to consider all road users.

3.5 Review of Other Literature

The second stage of the literature review was to identify pedestrian and cyclist safety and mobility issues in relation to traffic management schemes and treatments. The following sections discuss the issues determined for both pedestrians and cyclists.

3.5.1 Pedestrian Safety Issues

Literature has revealed that a significant proportion of fatalities and injuries, as a consequence of road crashes, involve pedestrians and cyclists both in Australia and overseas. Areas of particular concern for pedestrian safety include:

- Child pedestrian facilities
- Mid-block crossings
- Pedestrian crossing facilities at signalised intersections
- Facilities for people with disabilities
- Other Pedestrian Facilities

Child Pedestrian Treatments

Child pedestrians are considered to be vulnerable road users as their knowledge of traffic rules and their ability to interact with other road users is not developed to the same level of older road users.

Preston (1994) studied various schemes in place around the world to reduce child pedestrian fatalities. It is evident that the areas of most concern for child pedestrians are the journey to and from school and near their residence. Preston (1994) found that deaths per 100,000 were higher in some countries than others. The lower rate in some countries can be attributed to the introduction of safety measures.

Preston studied a number of methods that have been used in the attempt to reduce child pedestrian fatalities during the journey to and from school. These ranged from bus services that picked up and dropped off from home frontage, physical treatments such as raised crossings, traffic free pathways to the school and reduced speed limits in the school area. An example of the successful use of traffic management treatments is that of Odense, Denmark. The speed near schools was reduced to about 15 mph (24 km/hr) by physical means such as raised areas and raised crossings, humps and road narrowings. Before and after studies showed an 85% reduction in accidents after the introduction of traffic restraint measures (Preston, 1994).

Schemes to reduce accidents in residential areas include either completely or partially traffic free areas or traffic calming measures. These are appropriate in some areas but not others. Preston (1994) discussed a scheme suggested by Professor Howarth where child pedestrians should have priority. They were called “Home Zones”. Professor Howarth was also of the opinion that a driver striking a child in these zones should be presumed negligent.

The suitability of different treatments is dependent on the set of circumstances. Taking on board these circumstances, Preston (1994) recommends the following to be adopted to reduce child pedestrian accidents:

- Very low speed limits should be introduced outside schools;
- In suitable small residential areas speeds should be reduced to walking pace. This could be achieved by changing the law so child pedestrians have priority in these designated home zones.

Mid-block crossings

ETSC (1999) states that only about 50 per cent of pedestrian deaths occur while crossing a road and about a quarter while boarding or alighting from a bus or getting into and out of a car. Most fatal crashes involving pedestrians are not located at marked crossings, the vast majority occur more than 50m from such a crossing. The elderly are most likely hit when halfway or further across the street whereas children are mostly hit when starting to cross.

Hidas et al (1998) studied the effects of mid-block speed control devices on fundamental characteristics of traffic such as vehicle headway distribution, absorption capacity, and average delays to vehicles entering from driveways and pedestrian crossing opportunity. Hidas et al (1998) also looked at the positive effects of such treatments in terms of speed reduction and reduction of accidents.

From this study Hidas et al (1998) concluded that although speed control devices do have some negative side-effects which are sometimes statistically significant, the magnitudes of the increase in average delays and the decrease in absorption capacities around the device are below the level that would conceivably influence the practical crossing and merging abilities. These minor inconveniences to pedestrians and drivers, confined to the immediate vicinity of the devices, are by far outweighed by the benefits in terms of accident savings over the whole length of the street as a consequence of the speed reductions ensured by the presence of the devices.

Osmers (1998) describes traffic control devices that have been trialed in New Zealand. The two relevant to pedestrian safety are “PUFFIN’ crossings and the “Kea” Crossings.

A PUFFIN (Pedestrian User-Friendly Intelligent) consists of normal traffic signals with additional features such as when the pedestrian presses the button a tactile paving device or microwave device confirms that a person is waiting to cross. If the person moves away or crosses before the signal the device will cancel the demand so vehicles do not stop unnecessarily. The device also detects whether the pedestrian has crossed the road or is still on the road and extends the green signal if need be. The device was installed on a residential street near two schools, replacing three existing crossings. The traffic volumes are 12,000 vehicles per day with about 1400 vehicles in peak hour. Pedestrian volumes are 600 pedestrians per hour for the hour before and after school. Osmers (1998) received positive feedback from the schools regarding improved safety. There have been no reported accidents at the site since the crossing was installed, whereas six injury accidents at the three crossings were reported prior to the installation of the PUFFIN crossing.

Osmers (1998) describes a "kea" crossing as a part-time pedestrian crossing in the vicinity of schools. They operate only for about a half-hour before and after school and are patrolled by school children (supervised by an adult). Their operation is similar to that of patrolled zebra crossings but their layout is designed to be prominent when they are in operation and discrete at other times. Osmers (1998) outlines the following features of a "kea" crossing:

- kerb extensions,
- a single vehicle hold line and centreline marking on the approach,
- a pedestrian hold line behind the kerb on each side of the road,
- short "crossing point definition lines" marked at right angles to the kerb to define the width of the crossing point,
- swing-out "School Patrol" signs and supports on each side of the road (present when crossing operational), and
- fluoro-orange "Children" flag signs and supports slightly in advance of the crossing on each approach.

The children on patrol swing the signs out when there is a gap in traffic. Once traffic has stopped pedestrians cross the road. When children have stopped crossing the road the sign swings back providing a barrier for the awaiting pedestrians.

The "kea" crossing was trialed at 37 sites in New Zealand and was very well received. There was strong demand from schools in many centres for more to be installed.

Austroads (2000b) investigated the effectiveness of various types of mid-block crossings, namely, zebra and pelican crossings. Austroads (2000b) concludes the following from studies reviewed:

- Early studies in the UK found that the safety benefits of installing pelican crossings as inconclusive, although later studies have found them effective.
- UK data suggests that a higher pedestrian crash rate is associated with crossing at pelicans than crossing at intersection signals, although crossing movements made at pelicans on arterial roads have lower crash rate than crossing movements made away from crossing facilities.
- A high crash rate was associated with crossing close to a pelican crossing rather than on the crossing itself.
- NSW data suggests that both pelican crossings and standard Pedestrian Operated Signals significantly reduce pedestrian crashes.
- There is conflicting evidence on the safety of zebra crossings.

Pedestrian crossing facilities at signalised intersections

From the discussion provided by Austroads (2000b) there seems to be a trade off between the degree of protection to pedestrians and the delay to vehicles when considering the type of pedestrian crossing treatment. Austroads (2000b) looked at studies undertaken to assess the effectiveness of pedestrian facilities at signalised intersections. They concluded there is a lower risk for pedestrians at signalised intersections, however, there is no conclusive evidence that the installation of traffic signals reduces the number of pedestrian crashes.

Pedestrian Facilities for People with Disabilities

Austroads (2000a) studied issues associated with needs of pedestrians with disabilities in the road environment. These road users included pedestrians with mobility impairment, vision impairment, colour vision impairment and pedestrians who use wheelchairs in the road environment. They discuss how engineering road treatments can often lack the necessary details suitable for the needs of people with disabilities. Some examples provided by Austroads (2000a) for inclusion in Austroads Road Safety Audit, which are also applicable when considering the safety of pedestrians, include:

- Is the crossing identifiable to the people with vision impairments?
- Is there a distinct boundary at the edge of the footpath and the road surface?
- Are pedestrian refuges wide enough to accommodate wheelchairs? and
- Is the crossing pavement flush with the roadway surface at each kerb and intermediate island or median?

Austroads (2000a) discusses further some of the traffic control and design issues, which accommodate the needs of pedestrians with disabilities. People with disabilities need to be considered at the planning and design stages of infrastructure projects to provide pedestrian facilities that are accessible to people with disabilities and thus the whole population.

Other Pedestrian Facilities

Austroads (2000b) examined various studies regarding the safety benefits of pedestrian refuges and medians. They concluded the following:

- Medians are highly effective in reducing pedestrian crashes;
- In general, pedestrian refuges appear to have been highly effective in reducing crashes. However, the NSW data is inconclusive on this score. However, it may be that, as with the zebras, more people are attracted to cross at that point, and study of the accident history of whole streets rather than a specific site is called for.
- Kerb extensions have been effective in reducing crashes.
- Raised platforms have also proved to be very effective in reducing pedestrian crashes.
- Raised pedestrian platforms with marked crossings have also been successful, although less than some of the other countermeasures.

Another potential danger to pedestrians is that of “pseudo” crossings (ie. textured or coloured surfaces) which do not constitute a legal crossing point, but which may lead pedestrians to believing that it is a legal crossing point and that they hence have a “right of way” over vehicles.

3.5.2 Bicycle Safety Issues

ETSC (1999) states that most fatal or serious crashes, in relation to cyclists, occur at junctions. Many are struck from the side while going straight ahead or turning across the path of oncoming traffic. For cyclists, the death rate per head is highest between the ages of 10 and 17 (ETSC, 1999).

Literature has identified the safety concerns exist where cyclists conflict with other road users. These location include:

- Road narrowings;
- Signalised and unsignalised intersections;
- Paths and road junctions
- Roundabouts

Road Narrowings

A considerable amount of literature was found pertaining to the effects of road narrowings on cyclists. There was a common theme throughout the articles that the narrowings are effective in reducing the speed of motor vehicles, however, they were often designed with no consideration to the safety of cyclists. Maher (1994) states the most common problem for cyclists has been the conversion of a wide carriageway (with ample space for cyclists and cars to share the lane) to a narrower lane, by the placement of kerb extensions, or median islands, or both. The result is a "narrow pinch point" or "squeeze point", with cyclists having to share a narrow space with cars, and often being forced off the road to avoid a crash.

The Scottish Executive (1999) discusses potential problems of street narrowing. Despite their effectiveness to reduce traffic speeds, cyclists may feel at risk due to the reduction in carriageway width available. If there is no alternative cycle facility, cyclists may find themselves closer to motorised vehicles especially heavy goods vehicles (HGV's) and motorists may continue to pass cyclists within the narrowed area.

DETR (1997b), in the UK, states cyclists have expressed concerns about the design of some traffic calming features, particularly those, which involve narrowing of the carriageway. A prevalent feeling of being "squeezed" by motor vehicles over-taking within the narrowing, or being pressured by vehicles following close behind. TRL (1997) carried out research to examine the safety and convenience of cyclists at road narrowings. They carried out a literature review, a reconnaissance survey, video filming and cyclists interviews. They looked at various lane widths and types of narrowings. DETR's research has shown that drivers do not appear to alter their overtaking behaviour at narrower sites or sites with cycle lanes. Although there is no evidence that cyclist accidents increase as a result of introducing road narrowings, such facilities can increase cyclists' anxiety and perception of danger. In the context of promoting cycling, the width of running lanes of narrowings, or bypasses to enable cyclists to avoid narrowings, should be considered.

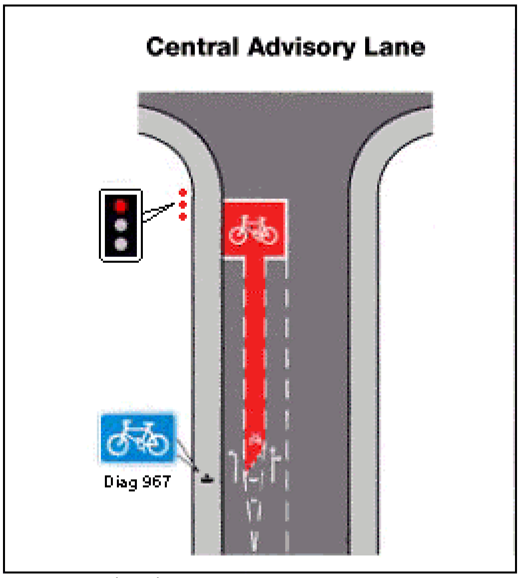
Intersections

It is common in Australia for intersections to have no bicycle facilities with cyclists having to share the roadway with vehicles. This creates safety concerns for cyclists. In particular, conflict exists between these two road users when cyclists are entering the intersection and vehicles want to undertake turning manoeuvres. Adding to this confusion, intersections and traffic management treatments at intersections, are not necessarily designed in a way that provide a clear message to road users as to the expected behaviour of each type of road user.

A number of bicycle treatments are available for use at intersections. However, the review of literature has identified two types of treatments that are of particular concern for the safety of cyclists at intersections. Firstly, where a dedicated cycle lane is provided and secondly, where a cycle path enters the intersection.

Cumming (1996) discusses a cyclist safety issue frequently discussed in literature where there is conflict between turning motorists and cyclists using a dedicated cycle lane. For example, where the cyclists travel to the left-hand side of the motorist potential conflict exists when either the cyclists or motorists want to undertake a turning manoeuvre. This is where a traffic control device must provide a clear message to the cyclists and the motorist.

Herrstedt (1997) discusses methods to overcome this conflict including marking of the cycle lane so that it continues across the intersection. This indicates to cyclists where to go and reminds drivers to be aware of cyclists. Recessing the vehicle stopline by 5m (ASL) to reduce the number of accidents involving vehicles turning right and cyclists travelling straight ahead where traffic lights change from red to green. Danish research show that the number of this particular type of accident is reduced by 35% after introduction of the recessed line. DETR (1996) have studied the development of the ASL and have investigated further design advice for ASL for cyclists for central cycle lanes and nearside cycle lanes (refer Figure 1).

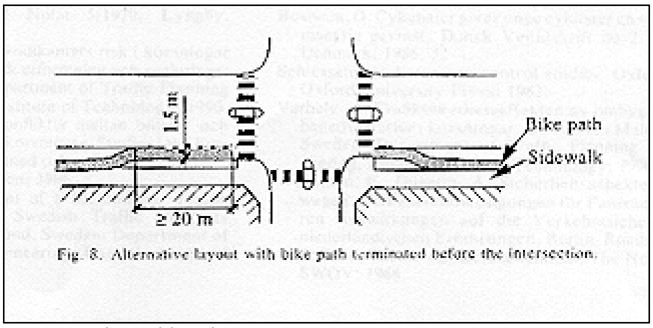


Source: DETR (1997)

Figure 1: Diagram of Advanced Stop Lines for centre lanes

Another conflict between the motorist and cyclists is where cycle paths meet intersections. Herrstedt (1997) provided information regarding studies from Denmark, the Netherlands, Germany, and Sweden where the problems associated with cycle paths at intersections controlled by traffic lights have been emphasised. The studies revealed that extended cycle tracks appear to be a particular source of problems in some cases. Experiences indicate cycle lanes or truncated tracks might be preferable for cyclists entering the intersection area. However, this can create security problems for cyclists, as they have to mix with vehicle traffic on a shared area. A solution offered by Herstedt (1997) is the truncation of the cycle track 20 to 30m before the intersections and continue the marked cycle area into a cycle lane separated from vehicle lanes by a 30cm wide painted rumble line.

Garder et al (1994) discusses safety implications of cycle paths at signalised intersections. They state that the introduction of a cycle path would increase the risk to cyclists by 40% with the probability that the effect will be the opposite of 2%. Due to this increase in risk to cyclists they have suggested an alternative layout where the bike path terminates prior to the intersection (refer to Figure 2). Note Garder et al (1994) provide no evidence to suggest this type of layout is a safer alternative.



Source: Garder et al (1994)

Figure 2: Suggested layout by Garder et al (1994)

In Australia it is common that intersections have no bicycle facilities

Intersection of Bicycle paths with roads and driveways

Cumming (1996) discusses a case study in Footscray, Melbourne where an off-road commuter cycle path intersects with one entry and two exit driveways of a service station.

Source: Cumming (1996)

Figure 3: Footscray Road Bicycle path and service station driveway intersection

The cyclists have priority and there are signs and line markings to convey this message. Through personal experience, Cumming (1996) considers the device not particularly effective. To improve the treatment Cumming (1996) recommends the use of regulatory signs instead of advisory signs to stop vehicles and standard line marking used for vehicles to give way.

Cumming (1996) discusses road treatments where a bicycle path crosses a suburban road. In order for the cyclist to have right of way there must be sufficient messages given to motorists to ensure that they are fully aware they must give way to cyclists.

Source: Cumming (1996)

Figure 4: Zwolle, The Netherlands — Cyclist priority at road crossing

Cumming (1996) provides an example from Zwolle in the Netherlands where a treatment has been successful in providing a clear understanding of expected behaviour for both vehicles and cyclists (Refer Figure 4). The characteristics of the treatment are – a speed hump used to control motorist speed; pavement colour has been used in three different locations being AC pavement colour, paver colour on the approaches to the speed hump and the bicycle path; small amount of line marking has been used on the approach to highlight the ramps on the speed hump; signs comprised of give way sign in conjunction with bicycle and moped directional signs; and graphics in the form of triangles painted on the edge of the speed hump also used to designate the give way. In addition speed limit 50 km/h and sight distances are appropriate for the required stopping distances at that speed.

Cycle Lanes on Roads

Herrstedt (1997) discusses research carried out over the years to describe safety effects of cycle tracks and lanes in Denmark and many other countries. The overall conclusion is that off-road cycle tracks and on-road cycle lanes have strong beneficial safety effects for cyclists on urban road stretches between intersections. Studies from Denmark show reductions around 35% in cyclist casualties on stretches after construction of tracks or lanes along urban roads.

Cyclists and pedestrian conflict

Cumming (1996) provides an example in Swanston St, Melbourne, which is now a low traffic volume street and has been significantly enhanced for pedestrians and cyclists. However, conflict exists when:

- Pedestrians cross mid block (without using traffic signals) conflicting with cyclists;
- Cyclists do not stop at red stop signals conflicting with pedestrians on the road;
- Tram passengers are alighting and cyclists do not stop.

Cumming (1996) suggests the designer has used a limited number of techniques to deliver the message regarding the expected behaviour of pedestrians and cyclists. The designer has not provided a clear message of expected behaviour of all the parties. An opinion expressed by Cumming (1996) regarding cyclists disobeying red signals is that there is a high probability of having to stop every 120m at a red signal and the associated frustration. However, this does not excuse the behaviour.

Cumming (1996) discusses techniques used to reduce pedestrians and cyclists conflict. In Helsingborg, Sweden one way bicycle paths have been used in what is traditionally the pedestrians area. Figure 5 shows effective use of colour, texture, and pattern in the pavement to physically provide a clear message of expected behaviour.

Source: Cumming (1996)

Figure 5: Helsingborg, Sweden — Cycle path through pedestrian area

Herrstedt (1997) discusses cyclists/pedestrian conflicts at bus stops. Denmark is trialing marking the conflict area that occurs between cyclists and pedestrians. Experiences are so far positive.

Cyclists and Lorries

DETR (1997a), in the UK, has identified that conflict exists between cyclists and heavy goods vehicles in the road environment. The National Cycle Strategy (UK) has noted that a disproportionate number of serious and fatal injuries to cyclists involve accidents with large goods vehicles. Measures suggested by DETR (1997a) to reduce this include:

- Cycle routes should be planned to avoid routes frequently used by lorries;
- Similarly lorry routes can be planned to avoid roads commonly used by cyclists;
- A nearside lane of 4.25m will allow lorries and cycles to comfortably pass each other;
- Guard railing – there is concern about the location of guardrails at junctions, where cyclists have been injured as a result of being caught between a lorry and guardrailing. Ensure only the necessary length of guardrail is provided.

Roundabouts

Literature suggests that cyclists' safety is compromised at roundabouts. Although some studies on this issue have shown that there are benefits to cyclists from using smaller roundabouts (as they reduce vehicle speeds) larger roundabouts are typically more of a hazard to cyclists due to the greater speeds travelled by vehicles. In the UK cyclists are 15 times more likely than other car users to suffer a crash at a roundabout. Over half of these crashes are due to motorists entering the roundabout and hitting cyclists (Layfield and Maycock 1986, cited ETSC, 1999).

A study conducted by Elvik's (1995) in Norway concluded roundabouts work well for cyclists with a 30-40% reduction in personal injury crashes. These were on roads with relatively low vehicle flows and speeds but high flows of cyclists.

ETSC (1999), provide ways in which roundabouts can be made safer for cyclists. These include:

- Reducing width of circulatory carriageway;
- Increase deflection on entering;
- Improving signage, road markings and conspicuity

The Scottish Executive (1999) provides options to reduce the conflict between the motorists and cyclists and provide a table giving general guidance for roundabouts.

3.5.3 Safety Issues Applicable to Both Pedestrians and Cyclists

Literature suggests that new Intelligent Transport Systems (ITS) are being developed with emphasis on the motor vehicle. Austroads (2000b) investigated various ITS and made the following conclusions:

- Developments in ITS are likely to increase traffic flow and increase traffic speeds over much of the road network, making crossing the road even more difficult for pedestrians and cyclists unless steps are taken to avoid this outcome.
- The various ITS programs seem to offer little that is specifically directed to improving pedestrians and cyclists safety.
- The devices that are likely to have the greatest impact are those that affect pedestrian/vehicle interactions at crossings rather than in-car devices or those carried by pedestrians.
- Effective loops are available for bicycle detection.
- There would appear to be room to improve the performance of infrared detectors for use at Puffin crossings.
- Vision-based detection systems are promising, but are not yet suitable for pedestrian detection in outdoor traffic situations.
- Pedestrians and cyclists appear to have few problems using the new Puffin, Toucan and Advanced Stop Line crossings. However, some concerns remain regarding the safety implications of the large number of vehicles intruding into the cyclist reservoir at Advance Stop Line crossings.
- Puffin crossings deliver improved crossing opportunities to pedestrians, particularly the elderly or people with disabilities, without unacceptable delays to traffic. In some circumstances, a Puffin crossing may reduce delays to traffic.

3.5.4 Pedestrian and Bicycle Mobility Issues

Typically, a number of the safety issues raised in earlier sections of the report impact on the mobility of pedestrians and cyclists. Generally in the past, pedestrians and cyclists have not been given equal consideration in the design and implementation of traffic management treatments resulting in reduced mobility. Some issues associated with the mobility of pedestrians and cyclists are discussed below:

- It was discussed by Preston (1994) that home zones could be considered in residential areas to reduce the number of child pedestrian accidents. Although this is predominantly a safety measure it would also improve the mobility of pedestrians as well.

- Unless alternate facilities are provided for cyclists at street narrowings, kerb extensions or median islands mobility of cyclists is restricted due to the reduced area that is shared with motor vehicles.
- Cumming (1996) provides an example where the mobility of cyclists has not been considered in traffic management treatments. Along Swanson Walk, in Melbourne, the layout of the road environment is such that cyclists have to stop approximately every 120m. Evidently this appears to frustrate cyclists resulting in some cyclists disobeying red light signals.
- Road closures are carried out to reduce the number of through vehicles. However, this is often carried out without providing alternate facilities for cyclists thus effecting the mobility of the cyclists. Maher (1994) expresses that Local Area Traffic Management devices such as road closures are put in place severing existing bike routes with no provision for cyclists or pedestrian movements.
- By not providing appropriate facilities for people with disabilities their mobility is greatly affected and their safety compromised. Austroads (2000a) discusses these issues as mentioned in section 3.5.1.
- Infrastructure for pedestrians and cyclists needs to be provided to improve the mobility of these road users, including clear, smooth and unobstructed paths of travel, appropriately designed and built pram ramps, tactile information for pedestrians with vision impairments, guidance for pedestrians, amenities such as shelter, awnings and seats and street lighting for personal safety.

3.6 Summary of the Literature Review

The following key points have been drawn out from the literature review:

- A trend that has emerged from reviewing the literature, which concerns both the mobility and safety of pedestrians and cyclists is that traffic management treatments are being designed that fail to provide a clear message as to the expected behaviour of all road users.
- A treatment that is commonly used as a form of traffic management is street narrowings. These are successful in reducing speeds of motor vehicles, however, they are perceived as dangerous for cyclists as they are forced to share a smaller space with motor vehicles. A solution to this problem is the provision of alternate facilities for cyclists. Part 14 raises this issue and provides alternatives such as by-passes around the narrowing for cyclists.
- Review of the literature has identified that 50 percent of pedestrian fatalities occur while crossing a road. This highlighted the need to provide appropriate crossing facilities in the most suitable locations for pedestrians.
- Vehicle and cyclist conflict occurs at intersections, especially where a cycle lane exists but traffic and cyclists need to make turning manoeuvres. Literature shows that Advanced Stop Lines (ASL) have been a successful treatment to enhance the safety of cyclists at signalised intersections. This particular treatment and others have been included in Part 14.
- A safety issue identified for cyclists is where cycle paths meet roads and intersections. This is discussed briefly in Part 14. Although the literature reviewed identified this issue, there was mixed opinions whether to truncate a cycle path prior to an intersection and provide a bicycle lane to get cyclists through the intersection. No evidence was provided to support this concept.
- Although research is an ongoing process and new concepts are continuously being developed, it seems that generally Parts 13 and 14 offer appropriate treatments that have been discussed in the literature for pedestrians and cyclists. However, this report did not focus on the types of treatments available.
- The review identified that more consideration could be given to including appropriate facilities for people with disabilities when designing road treatments.
- An interesting point raised in Austroads (2000a) is that *the various ITS programs seem to offer little that is specifically directed to improving pedestrians and cyclists safety.* This issue cannot be solved in this report, however, the effects of ITS with respect to pedestrians and cyclists need to be considered as ITS has the capacity to increase traffic flow and speeds over the road network.

4 Traffic Models Allowing for Pedestrians and Cyclists

The previous section of the report discusses a selection of safety and mobility issues pertaining to pedestrians and cyclists with respect to traffic management treatments. This provides an appreciation of the vulnerability of pedestrians and cyclists as part of the road environment. The types of issues identified tended to focus on detailed design issues regarding traffic management treatments.

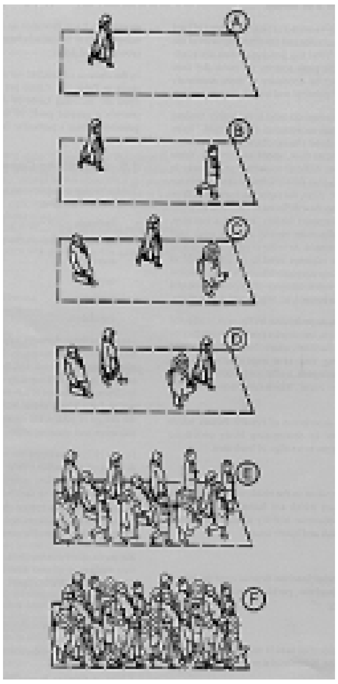
The next section of the report looks at modelling for pedestrians and cyclists. The focus of these models is predominantly at the network level or link based level rather than at the detailed level. Traffic models that have been identified have been categorised into pedestrian or cyclists models and range from manually based models to computer simulation models. A brief description is provided for each of the models identified under these headings.

A number of traffic models available have been developed primarily for the use of modelling vehicular traffic. However, some of these models have the capability to allow for pedestrians and or cyclists. These include but are not limited to TRIPS, SATURN, EMME2, Questor, SIDRA and Paramics. However, the focus of this study was on models that have been developed specifically for pedestrians and cyclists.

4.1 Pedestrian Models

Level of Service criteria in Austroads Guide to Traffic Engineering Practice Part 13

The level of service concept was pioneered by Fruin in early 1970's. The level of service criteria provided in Austroads Guide to Traffic Engineering Practice Part 13 has been adopted from the work undertaken by Fruin, which is based on density. An extract of the tables from Austroads Guide to Traffic Engineering Practice Part 13 is provided below. Commentary is provided in the document to support the material presented in the tables.



Level of Service	Module Size M (m^2/ped.)	Flow Rate (ped/m/min)	Sample Applications
A	> 3.3	23	Public Buildings or plazas without severe peaking fit this level
B	2.3 - 3.3	23 - 33	Suitable for transport terminals or buildings with recurrent but not severe peaks
C	1.4 - 2.3	33 - 49	Recommended design level for heavily - used transport terminals, public buildings or open space where severe peaking and space restrictions limit design feasibility
D	0.9 - 1.4	49 - 66	Found in crowded public spaces where continual alteration of walking speed and direction is required to maintain reasonable forward progress.
E	0.5 - 0.9	66 - 82	To be used only where peaks are very short (eg. sports stadia or on a railway platform as passengers disembark.) A need exists for holding areas for pedestrians to seek refuge from the flow.
F	0.5	Variable, up to 82	The flow becomes a moving queue, and this is not suitable for design purposes.

Source: Austroads (1995)

Figure 6: Level of service criteria — Austroads Guide to Traffic Engineering Series Part 13

Quality of flow along pedestrian arterials

Virkler (1996) presents a technique to evaluate the quality of flow along an entire pedestrian route. The methodology complements present level of service standards for walkways, stairs and queuing areas and is similar to the approach outlined in the Highway Capacity Manual for analysing urban and suburban arterials for vehicles. Virkler (1996) defines a route as *an identifiable pedestrian path (e.g. several city blocks) which carried a significant volume between major pedestrian generators*. The rationale behind the development of the set of analysis tools is that user satisfaction on individual elements of that route may differ markedly from satisfaction over the extended route.

Virkler (1996) outlines a series of steps to be taken to assign a level of service to the whole pedestrian route. This involves the identification of the route and the various links within the route, calculation of the walking time for each link, queuing time for each queuing location and average travel speed. Once these parameters are calculated a level of service for the pedestrian arterial can be assigned using the table presented in the paper, which is the adaptation of level of service standards for pedestrian walkways and the vehicle delay at signalised intersections. In addition, a level of service for each discrete walkway, stairway and queuing area can be assigned using tables provided.

Integrated systems methodology for pedestrian traffic flow analysis

Romer and Sathisan (1997) suggest that the pedestrian system is made up of three elements namely, sidewalk, intersection corner or holding area and the crosswalk. They discuss the interrelationship of specific aspects of these three elements, which have been categorised as geometric, traffic, or traffic signal operation related. Romer and Sathisan (1997) adopted existing level of service criteria and assumptions used in the Highway Capacity Manual to develop the methodology to design or evaluate existing signalised at grade intersection pedestrian elements and to develop decision support tools to evaluate the potential need for a grade separated pedestrian facility.

They proposed a methodology that could be used to develop a balanced level of service system based on desired level of service, corresponding pedestrian flow and effective walkway width for planning procedures, or could be used if actual conditions are known (Romer and Sathisan, 1997). A flow chart was developed, however, it was determined that one of the formulas inaccurately reflects the geometry of a sidewalk.

Pedestrian Access Model

A paper by Ash (1993) presents two computer programs that were developed to aid planning professionals in the evaluation of alternative station concepts, both for passenger flow and movement point of view and from road access and interchange access. These are the Pedestrian Access Model (PAM) and the Generation and Assignment of Road Traffic and Railway Stations (GartRail) respectively. As GartRail is not relevant to this study it will not be discussed.

PAM is able to model the following facilities – walkways (open areas and corridors), queuing areas, stairways, lifts, escalators, Universal Ticketing Systems gates, arrival/departure train capacity constraints, and one-way systems. PAM is a modelling tool, which enables transport planners to more accurately predict the impact of new or alternative station design concepts for railways.

For the evaluation phase of the model, level of service criteria has been adopted and is presented in the paper by Ash (1993). The outputs from the program include:

- Network speeds, total travel times and final queues after each iteration;
- Links with a ratio of flow to capacity of over 90% and/or affected by blocking back;
- Actual level of service for each time slice for each link;
- Worst case level of service across all time slices for each link; and
- Percentage distribution of level of service across all time slices for each link.

Also average walk distances and travel times for each origin and destination and any combination of origins and destinations can be extracted.

PEDROUTE

The PEDROUTE passenger simulation model was developed by Halcrow Fox in conjunction with London Underground Ltd. The computer program produces a detailed simulation of the movement of passengers in and around any point in space. It was originally developed for railway stations but can be employed in virtually any situation where there are congested pedestrian movements in confined areas. The model includes an integral dynamic assignment algorithm, which assigns passengers along routes through the study area taking into account bottlenecks and congestion. In stations PEDROUTE can model the arrival and departure of trains and the corresponding peaks and troughs in passenger flows. PEDROUTE contains an evacuation module to assess the safety of stations. Therefore, the application of PEDROUTE includes new and existing stations and can be used to undertake safety audits (Buckman and Leather 1994).

Various assignment methods are available, which range from fixed routes assigned by the user to dynamic assignment with quickest routes being determined by the program. Congestion is categorised by service levels developed by Fruin. PEDROUTE takes the service level a step further by the introduction of the service level factor, which takes into account the number of passengers that experience a particular service level (Buckman and Leather 1994).

The model provides statistics of journey time, delay and congestion for a pedestrian while travelling through a station, a stadium or other area. The simulation is used by the model to calculate flows, delays, crowding, service levels and service level factors. These are provided for the whole model or individual blocks. The output can be presented in the form of files or by graphical representation.

The package has been used on projects such as the Homebush Bay Olympic Site, Sydney Olympic Stadium and the Sydney Central Railway Station. It has also been used to conduct safety audits of 20 London Underground stations.

Station Congestion Model

The Station Congestion Model (SCM) was developed to model pedestrian activity at stations as it was foreseen that the increase in the use of public transport would impact on the congestion of pedestrian thoroughfares.

The SCM model is similar to the PEDROUTE model discussed previously, as SCM was modified for use in the PEDROUTE model. Therefore the applications of SCM are similar and include the design of new stations, the examination of improvements to existing stations, the investigation of the impacts of rescheduling trains and the implication of foregoing pedestrian space to commercial activities (Turner, Jones and Weston, 1991).

Outputs from the package include passenger densities of blocks selected by the user or a particular time during the simulation, output files containing volumes of passengers boarding or alighting, free flow and congested times for each block and route, and the percentage of time the number of pedestrians exceed a specified density level.

EVACSIM

EVACSIM is an evacuation simulation program taking into account a number of factors, focusing on human behaviour and pedestrian movement in highly stressed emergency evacuations. The approach used for this can be used in general pedestrian planning and design to evaluate efficiency of different types of walkways (Lovas, 1994).

The model assumes that any pedestrian facility can be modelled as a network of walkway sections. Pedestrian flow can be modelled as a queuing network process, where each pedestrian is treated as a separate flow object, interacting with other objects. Each individual is modelled separately (Lovas, 1994).

EVACSIM provides statistical results collected during the simulation and presents estimates to the performance measures. The primary performance measures for EVACSIM are the time it takes for a person to arrive at an exit and the number of persons who arrive at an exit within a particular time.

Cellular automata microsimulation

Cellular automata microsimulation has been successfully applied to modelling vehicular flows and traffic networks. The model is currently being applied to modelling bi-directional pedestrian flow. The model provides for simulating three modes of pedestrian bi-directional flow: - flow in directionally separate lanes, interspersed flow and dynamic multi-lane flow. So far the emergent behaviour that arises from the model, termed CA-Ped is consistent with well established fundamental properties (Blue and Alder, 2001). The author states that the model captures micro-level pedestrian dynamics with an intuitively appealing method and offers an experimental platform for better grasping the important parameters of pedestrian flows (Blue and Alder, 2001). Further development of the model is being undertaken.

4.2 Bicycle Models

Latent Demand Score Model

Latent Demand Score (LDS) model was developed to give bicycle planners the ability to quantify bicycle travel demand. The LDS model quickly estimates the probability of bicycle travel on an individual road or street segments based on the proximity, frequency, and magnitude of adjacent bicycle trip generations and or attractions (FHWA, 1998). FHWA (1998) outlines the steps to be undertaken in the model.

The LDS model uses readily available demographic data, employing simplified geocoding and data input for spreadsheet-based gravity computations. The LDS model also estimates the relative latent demand of bicycle travel on each segment of a road network. It provides a clear indication of the relative level of desired bicycle use should a bicycle facility be provided on the road segment (FHWA, 1998).

Operational Analysis of Uninterrupted Bicycle Facilities

Density is commonly used as a performance measure to assess pedestrian facilities. Density has been criticised as a poor performance indicator for bicycles as they do not use space as efficiently as pedestrians (TRB, 1998). TRB (1998) provide procedures to assess bicycle facilities using the concept of “frequency of events” where events are defined as bicycle manoeuvres required by a cyclist on a facility including passing (same direction encounters) and meetings (opposite direction encounters). The concept of “frequency of event” and procedures outlined by TRB, (1998) have adopted some of the work carried out in the Netherlands by Botma. Botma termed the concept of “frequency of events” as “hindrance”.

Methodologies are presented for off-street bicycle paths both one and two way, shared off-street paths and to a limited extent, on-road facilities. Calculations are made and then a level of service criteria is assigned. Tables presenting the level of service criteria are provided in the article by TRB (1998). Note these procedures are based on a Dutch approach and were recommended for adoption into future versions of the Highway Capacity Manual. However, the procedures require validation to account for the differences in cyclists behaviour, levels of experience, bicycle path widths and bicycle designs between the USA and Europe (TRB, 1998).

Bicycle Compatibility Index

A methodology was developed for deriving a Bicycle Compatibility Index (BCI) to evaluate the capability of specific roadways to accommodate both motorists and cyclists. The intention being to provide practitioners with the ability to assess bicycle level of service present on existing facilities or on proposed facilities. It can be used for operational, design and planning analysis (FHWA, 1998).

The following points outline the specific applications for the BCI presented in FHWA (1998).

- *Operational Evaluation*: Existing roadways can be analysed and the following can be produced: - a map of BCI for segments of the network; segments can be evaluated for future provision of facilities for bicycles to determine which segments are the most compatible for cyclists; weak links in the network can be identified; alternative treatments can be evaluated using BCI model.
- *Design*: new roads can be assessed to determine whether they are bicycle compatible.
- *Planning*: The model can be used to assess future roadways using projected volumes and planned roadway improvements to assess the bicycle compatibility.

The document presented by the FHWA provides information on using the BCI model, data requirements for using the model and a description of the workbook and or spreadsheet to facilitate its use. It also provides examples illustrating practical applications of the model.

ARRB Transport Research Ranking Procedure for Bicycle Projects

McInerney (1998) developed ranking procedures to prioritise projects designed to improve the ability of the road network to safely carry cyclists. In essence the procedures draw together the quantitative and qualitative aspects associated with cycling projects, whether they be benefits or costs.

From a qualitative perspective issues related to level of service, coherence and directness, attractiveness and comfort of the facility, safety, environment and health, strategic issues and the effect on other users are all catered for in an event tree analysis. The final ranking of projects is then completed using a combination of the quantitative and qualitative assessment results to provide a prioritised list of all cycling projects considered (McInerney, 1998).

QUOVADIS-BIKE

Quovadis-Bike (QVB) is a computer modelling package developed in the Netherlands specifically to model cycle networks. DETR (1995) outlines that this cycle traffic model can assist in the identification of routes, and provide valuable information to help determine the facilities to be implemented along these routes, but can not offer design solutions. Assumptions have been made relevant to the Dutch cycling culture, which need to be considered if using the model for Australian and New Zealand cycling circumstances. For example one of the assumptions is that a modal share of 29% for cycling is observed as in the Netherlands (DETR, 1995).

From discussion with Mr Howard Boyd, QVB has been put aside by the Dutch as it is currently DOS based and requires costly conversion to a windows package (Personal communication, Howard Boyd, Senior Traffic Engineer, Babtie Group, Scotland 22/3/2001).

Bicycle Simulation (BICSIM)

The university of Delaware in Newark USA has developed a traffic simulator that allows for both bicycle and motor vehicle traffic. The objective of the model was to "*improve the road design for cyclists and, in particular, refine the inadequate facilities of bicycle transportation on road networks* (Faghri and Egyhaziova, 2001). The steps taken to develop the model include data collection and review of published theories to provide an understanding of the problem.

The core algorithm for the microscopic simulation model was to incorporate both the characteristics of motor vehicles and bicycle traffic. It also takes into consideration both the dynamic and the stochastic nature of the problem over an entire network. Other factors that needed consideration included pedestrians, parked cars, and bus stops.

The outputs from the program include the number of vehicles (bicycles, cars, and all vehicles) on each link and the entire network, travel time, travel speed, delay, and fuel consumption for each section of the roadway and the entire network.

4.3 Pedestrian and Bicycle Models

Pedestrian and Bicycle Crash Analysis Tool

The Pedestrian and Bicycle Crash Analysis Tool (PBCAT) is a package developed by FHWA in the USA, with the objective to assist state and local government pedestrian and bicycle coordinators, planners and engineers in the attempt to reduce the number of pedestrians and cyclists fatalities. PBCAT achieves this goal through development and analysis of a database containing details associated with crashes between motor vehicles and pedestrians or cyclists. With the database developed, the software can than be used to produce reports and select countermeasures to address problems that are identified (FHWA, 2000).

Other Level of Service Criteria

The Highway Capacity Manual has procedures for determining level of service for pedestrians with principles similar to that used in determining level of service for traffic. The criteria used for level of service ranges from pedestrian speeds and flows to more subjective criteria such as comfort, convenience, safety, security and economy of effort.

Other level of service models exist for both pedestrians and cyclists facilities whereby a score is assigned to certain characteristics of the facility. These scores are weighted and a total is calculated. An overall level of service indicator is then assigned to the facility.

5 Conclusions

A review of literature identified safety and mobility issues pertaining to pedestrians and cyclists with respect to traffic management treatments. These issues tended to revolve around detailed design issues. It was envisaged that these issues might have been addressed in traffic models that allow for pedestrians and cyclists. However, the traffic models identified looked at traffic management at a network or link-based level and therefore did not address the specific issues identified earlier in the report.

The method adopted for assessing pedestrian facilities in the current Austroads Guide to Traffic Engineering Part 13 is the level of service criteria developed in the early 1970's by Fruin. The basis of Fruin's criteria for assessing pedestrian facilities is density. Our review of the literature suggests that this approach is still relevant and current. However, level of service has been taken a step further by Virkler (1996) and Romer and Sathisan (1997) who have developed methodologies to assign a level of service to the whole pedestrian route as well as individual elements.

A number of computer models were identified that simulate pedestrian activity over a pedestrian network. Many of these have been developed for railway stations but they can be applied to other pedestrian facilities as well.

It would seem that Austroads Guide to Traffic Engineering Practice Part 13 level of service criteria is still relevant and current, however, reference could be made in the document to other techniques available for assessing pedestrian facilities.

Austroads Guide to Traffic Engineering Practice Part 14 offers detailed design criteria for assessing specific features of bicycle facilities. However, no tool is provided for assessing a bicycle route as part of a network. Again, the accepted practice for assessing bicycle facilities is some form of level of service criteria.

The methods that were identified include:

- The LDS model which indicated the latent demand of bicycle travel on road segments;
- A level of service concept developed in the Netherlands for analysing uninterrupted bicycle facilities has been modified by TRB (1998) and is based on "frequency of events". It is to be noted that the procedures outlined for this technique require validation to account for differences in cycling between the USA, Europe and Australia/New Zealand;
- The Bicycle Compatibility Index developed by FHWA (1998) to assign a level of service to bicycle facilities. This analysis tool determines the bicycle compatibility of new or proposed roadways.
- Bicycle ranking procedures, developed by ARRB Transport Research, prioritise bicycle projects to improve the ability of road networks to safely carry cyclists.
- Computer models were identified that simulate bicycle activity. These models include QVB, which specifically models the cycle network.

It is suggested that a level of service technique would be a useful tool for inclusion in future revision of the Austroads Guide to Traffic Engineering Practice Part 14. Furthermore, it is concluded that there would be benefit in including other methods available for assessing bicycle facilities as outlined in this report.

It is recommended that the research findings from this study should be referenced when the current Austroads Guide to Traffic Engineering Series Practice Parts 13 and 14 are reviewed.

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KEYWORDS:

Traffic flow, traffic models, pedestrians, cyclists, safety, mobility.

ABSTRACT:

In the past traditional traffic management has focused on motor vehicles with minimal consideration given to other road users such as pedestrians and cyclists. As a consequence pedestrians and cyclists can often experience mobility constraints and risks to their personal safety as a result of traffic management treatments.

This report, *Traffic Flow Models Allowing for Bicycles and Pedestrians* involved identifying models that consider pedestrians and cyclists and their relevance for use in Australia and New Zealand.

The first stage of the study involved a review of Australian, New Zealand and overseas literature to identify safety and mobility issues associated with pedestrians and cyclists and traffic management treatments. The second stage of the project investigated traffic models that allow for pedestrian and cyclists.

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