Bicycle Crashes

in

New Zealand

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in
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Abstract

The objective of this study is to consider safety aspects of the New Zealand cycling environment.

Cycling is one of the cheapest and most sustainable forms of transport, and for short distances in congested urban areas it is often the fastest. Cycling has strong potential for improving sustainability in urban transport. It is safe in the sense of presenting a low threat to others but dangerous in the sense of vulnerability to risk imposed by others. The major safety problem is sharing space with motor vehicles on roads designed and used with little or no thought for cyclist's needs.

A database maintained by the Land Transport Safety Authority is used to show that over 85% of serious and fatal cycle crashes fall into only 14 types of crash. These are analysed for frequency of fatal and serious injuries, the effects of cyclist's age, and changes over time. Each of the selected crash types is analysed for common contributing factors.

Bicycle facility design manuals from Australia, the Netherlands and the UK are used to develop proposals suitable for New Zealand conditions. The focus is particularly on methods of reducing risk in the most common crash situations.

However, engineering measures cannot be effective in isolation. Non-engineering measures needed to improve cycle safety include legislation changes; a fundamental review of the thinking behind present road safety practices; and estimation of the costs and benefits of enhanced cycle use.

Practical recommendations cover cycle lane design, cycles sharing space on roads, footpaths and bus lanes, and areas where traffic speed and volume make separate cycle provision necessary. However, most cycle crashes happen at road junctions and this is the area where present cycle provision is weakest. Recommendations are developed for guiding bicycles through junctions in safety, particularly when turning right or in situations where other traffic is turning.

Key Words: Bicycle; Transportation; Safety; New Zealand

In memory of the cyclist killed in crash number 96/10042

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The views, prejudices and errors are mine.

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1 Introduction

1.1 General introduction

In the main centres of New Zealand, cycling accounted for 4.1% of trips to full-time work[1] in 1996, down from 4.5% in 1991 (Statistics New Zealand, 1992, 1997). The Ministry of Transport (MoT, 1992) gives cycling as 3.7% of all trips in 1989–90 but only 1.1% of vehicle kilometres. In contrast, over 20% of commuter trips are by cycle in several European cities, with 60 % in Zwolle, Netherlands (Fietsersbond, 1997).

Broadly, eighteen cyclists a year are killed on New Zealand roads, 2.5 % of total road crash fatalities. Numbers are declining slowly. Reported serious injury crashes are 200 a year, 5% of the total, and other reported injuries 700 a year. Many injury crashes are not reported: reporting rates are thought to be 40–50%. The total cost is some $160 million a year, plus a similar amount for non-reportable crashes: those not involving a motor vehicle. There are also costs due to trips being suppressed or diverted to other modes by poor conditions for cyclists. For example, a guide to cycle touring recommends that cyclists do not ride in to the capital, but instead take the train from Paraparaumu or Upper Hutt (Ringer, 1994, pp 134, 162).

Apart from declining numbers this situation has not changed much since 1980, when computer-based crash records begin. However, two things have changed.

- Environmental and social sustainability have become issues in transport. Examples range from the recent Koyoto agreement to the pricing studies carried out by the Ministry of Transport (MoT, 1995, 1996). Cycling has the lowest environmental impact of any form of wheeled transport (Royal Commission on Environmental Pollution, 1997). For short trips it is the most economically sustainable transport mode.
- User-pays philosophy has spread to transport, bringing a risk of further neglect.

On the positive side, there is a wide-ranging debate on the future of transport in New Zealand, with fundamental reviews, detailed studies and widespread consultation.

Several new and old threads are coming together to make improved provision for cycling a logical development.

- An increasingly sedentary lifestyle is causing major medical problems (Swinburn, 1997), and cycling is very good exercise (British Medical Association, 1992).

  Cycling is an ideal means of sustaining a commitment to exercise throughout life, because its physical demands can be easily adjusted to levels appropriate to each individual's level of fitness and it can form part of the daily routine of travelling to school, college or work.
- Cycling provides good short distance transport on two out of three criteria in the MoT's vision (1996) for *safe, sustainable transport at reasonable cost,* but safety is a major limitation (British Medical Association, 1992, Bachels, 1996).
- Highway building is much less effective in reducing congestion than traditionally assumed (Standing Advisory Committee on Trunk Road Assessment, 1994). Banister (1994, p 157) says that *all available road construction policies only differ in the speed at which congestion gets worse, either in its intensity or its spread.*
- Transport demand is more elastic than traditionally assumed. Reducing motor traffic is practicable, economically viable and—in Europe at least—increasingly acceptable (Hass-Klau, 1997). Giving more road space to cycles, pedestrians and public transport has much less effect on traffic than has been assumed (Cairns et al, 1998).
- The average length of an urban trip by car is only about 5 km (MoT 1997a, p 60). Another estimate is 47% less than 3 km (MoT, 1993). Either puts many car trips well within cycling range. Other trips can be made by combining cycling and public transport: cycling increases the catchment area of a stop tenfold (Austroads, 1993, figure 2.3). The cycle can be left at the stop, or sometimes taken on public transport. Even in the United States, with urban residential densities lower than in New Zealand (Newman et al, 1990, Wood, 1991), 53% of the total population lives within 3.2 km of a public transport route (Department of Transportation, 1994), an easy cycling distance.
- Cycles use much less space than cars, for both travelling and parking. In urban areas they maximise use of a scarce resource.
- Cars are most polluting on short journeys, because the engine is cold, so transferring short journeys to cycling has disproportionately beneficial effects.
- On congested streets cycling may be faster than a car even for trips as long as 10 km (McClintock, 1992, p 13). Journey time is less variable than for cars because getting stuck in traffic is much less likely (Fietsersbond, 1997).

[1] 'Did not work today' and 'Worked from home' excluded

- The cost of making a city 'cycle friendly' is very low in urban transport terms, and substantial benefits are available. McClintock (1992, p 7) says that if Groningen (Netherlands, population 100 000) were to change from the present 50% of commuters on cycles to a more typical 5%, a further 22 hectares of central area land would be needed for car parking.

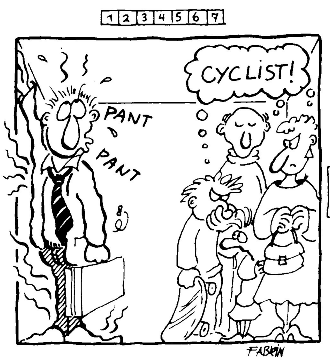
1.2 Cycle safety

Atkinson and Hurst (1984) say that *New Zealand would seem to be an unusually dangerous place to ride a bicycle.* It still is.

The Land Transport Safety Authority (LTSA) gives the average cost of road risk as 9 cents/km (LTSA, 1996), and considers the risk to be high if it exceeds 12 c/km (LTSA, 1995, p xi). The average cost of cycling risk calculated in this study is 46 c/km but the range is very wide. Costs would be even higher if they included non-reportable incidents such as falls. However, cycling is safer than motor vehicle use in three senses.

- A cyclist presents a low threat to other road users (Davis, 1993).
- A frequent cyclist gains major health benefits which offset or outweigh the risks. Hillman (1997, p 25) points out that in the UK the life years gained by exercise is on average about 20 times the life years lost through cycle crashes.
- Cycling is safer than driving for high-risk drivers (Wittink, personal communication), and this has been confirmed in New Zealand (Section 9).

Matching best European practice in cycle safety could make a major contribution to urban sustainability and reduced transport costs. It would help to reduce New Zealand's *relatively high couch potato index* (Swinburn, 1997), and would minimise an important barrier to greater cycle use—although other barriers would remain.



MoT, 1993b

1.3 Scope of studies

The intention of this study is to review safety aspects of the New Zealand cycling environment, identifying the most common crash types and reviewing overseas practice for countermeasures. However, engineering work cannot be carried out in isolation and the background of legislation and safety philosophy is also considered. The main conclusions are summarised in Section 12 and full recommendations are listed in Appendix A.

1.4 What cyclists are

Cyclists form a continuum from very young children to experienced racing cyclists and professional couriers. The age range is 2 to 84 years for the fatal crashes studied. No other group of wheeled road users shows such wide variation in age, skill and speed. The fastest cyclists maintain average speeds some four times greater than the slowest[2] and the instantaneous speed range is even greater. An equation in Centre for Research and Contract Standardisation in Civil Engineering (CROW, 1993, p 18) suggest that a cyclist weighing 80 kg and working at a constant hundred Watts will travel at 20 km/h on a level road but at 5 or 50 km/hr on a 9 % uphill or downhill gradient, a tenfold speed variation. A 40 km/h head- or tail- wind gives a similar range. In contrast, the speed difference during motor vehicle overtaking rarely exceeds 3:1.

Cyclists differ in skill at least as much as in speed, and it is hardly surprising that their needs vary. CROW (1993, p 19) says:

> *In some circumstances the rapid commuter cyclist is a standardiser for design (for example regarding the design speed). More often than not, however, the older cyclist who has a more limited physical capacity will determine standards (for example with regard to gradient percentages and crossing times). In yet other cases the design will be largely geared to young, inexperienced and sometimes inconsiderate cyclists (eg with regard to eye level, red light discipline and complexity of intersections).*

This continuum of cyclist's speed and ability can be broadly characterised as three overlapping groups.

- Children, family groups and elderly or inexperienced adults.
- Commuters and experienced adult cyclists.
- Sports cyclists.

Mountain bike riders are distinguished from other groups by off-road cycling, so for on-road purposes

[2] In the UK the fastest individual riders achieve 100 miles out and home in 4 hours, averaging 40 km/h

they can be included with the commuters or sports cyclists.

Two points are hidden in this continuum of speed and ability.

- For many people, perhaps most, the first experience of controlling a road vehicle is on a cycle. Cycling is a nursery of road skills, so effort put into good training of cyclists could have a much wider effect than safer cycling.
- Cycling requires balance. Cyclists need room to wobble, particularly when inexperienced, at low speeds, on rough surfaces or in windy weather.

1.5 What cyclists want

One approach to identifying cyclist's needs is the 'Five main requirements' given in CROW (1993, p 24). Three of them have safety implications.

Coherence

> *The cycling infrastructure forms a coherent unit and links with all departure points and destinations of cyclists.*
> Gaps in cycle routes may be dangerous areas for cyclists.

Directness

> *The cycling infrastructure continually offers the cyclist as direct a route as possible (so detours are kept to a minimum).*
> Cyclists will tend to avoid a route that is too indirect or has too many delay points, often choosing a more dangerous route. CROW suggests that delays should be less than 15–20 seconds per kilometre on primary routes. The most direct routes, averaged across a city, should not be more than 20% longer than the routes as the crow flies.

(Attractiveness) —

Safety

> *The cycling infrastructure guarantees the road safety of cyclists and other road users.*
> Social safety is also a consideration. CROW suggest that there should always be at least two routes available, of which at least one is safe at night.

(Comfort) —

Another approach to cyclist's needs is given in McDonald (1977) which I have adapted after seeking comments from cycling groups.

- Smooth and well-maintained surfaces.
- Segregation from heavy or fast-moving traffic and safe behaviour from non-segregated traffic.
- Cycle facilities kept free of parked cars, wherever possible with enough space to ride two abreast and to maintain any chosen speed.
- A well connected system of shared and segregated routes so that any journey can be made quickly, directly and safely.
- Freedom from artificial barriers creating unnecessary delays, such as excessive waits at traffic signals, sharp curves, narrow routes preventing overtaking of slower riders, long diversions or steep slopes for grade separation.
- Well signposted routes, so that cyclists can find them easily and know where to go at junctions, and other road users know where to expect cyclists.
- At key points, protection against danger from extreme weather conditions such as strong crosswinds (mainly Wellington!) or an icy surface on a bridge.
- Protection from social risks such as robbery in an underpass.
- Safe cycle storage at destinations, preferably with showers also available.

1.6 Quotations and copied diagrams

In this study quotations and diagrams from overseas practice are altered, where necessary, in three ways.

- Diagrams from countries where driving is on the right are reversed to show potential New Zealand practice. Similarly, references to left and right in the text are transposed to show New Zealand practice.
- Traffic flows expressed in vehicles per day (annual average daily traffic) are converted to peak flow vehicles per hour, using an assumed conversion of 10.0. O'Flaherty (1997, figure 17.1) says that this is typical of about the 20th to 50th busiest hours in the year.
- Data in imperial units is converted to SI units, although speeds are given in the more usual kilometres per hour.

1.7 Definitions and abbreviations

The following definitions and abbreviations are used in this study. I have chosen not to follow the definitions in National Roads Board and Urban Transport Council (1985) because of their limited scope, and instead have used definitions closer to European practice. The definitions of Cycle, Cycle Street, Crowding, Pinch Point and Reservoir are my own, and are intended to either clarify existing terms or suggest terms for practices which are new to New Zealand.

Advanced Stop Line:
: A cyclist's stop line at traffic signals, placed ahead of the motor traffic stop line to improve driver's visibility of cyclists. See also Reservoir.

Advisory Lane:
: A traffic lane primarily for cyclists and with priority for cycles at all times, but available to be used or crossed by motor vehicles when necessary. See Mandatory lane, but note that there is no distinction between Advisory and Mandatory lanes in present New Zealand law.

Bicycle or Cycle:
: A vehicle on two to four wheels with a maximum width of 0.75 m (CROW, 1993), powered largely or entirely by human effort, including any trailer but excluding wheelchairs[3].

Bus-cycle Lane:
: A bus lane on which cycles are permitted, in one direction for buses and in the same or both directions for cycles.

Contra flow track or lane:
: Cycle provision in what is otherwise a one-way street, in the opposite direction to general traffic flow, or on the 'wrong' side of a two way street to avoid cyclists having to cross traffic twice.

Crowding:
: A motor vehicle overtaking a moving cycle and passing so close that the cyclist is forced to change his or her intended course, due to the destabilising effect of air flow around the motor vehicle, or a real or perceived risk of collision.

Cycle Lane:
: A marked lane for cycles within the width of an ordinary road.

Cycle Track:
: A separate track for cycles, segregated from provision for other vehicles. A cycle track may be alongside a road but separated from it by a kerb and safety strip, or may be on an entirely separate alignment.

Cycle Route:
: A continuous route for cyclists, signposted as a coherent whole, usually including a range of facility types.

Investigating Officer:
: The officer investigating a road crash, whether a Traffic Officer or Police Officer.

Key Vehicle:
: The vehicle represented by a bold arrow in the relevant LTSA movement code diagram. See Appendix G.

LTSA:
: Land Transport Safety Authority.

Mandatory Lane:
: A traffic lane exclusively for cyclists. Use by motor vehicles is permitted only in emergency or for property access. Note that Mandatory lanes are not recognised in present New Zealand law.

MoT:
: Ministry of Transport.

Movement Code:
: A crash type in the coding system used by the LTSA. See Appendix G.

Pinch point:
: A location where the space for cyclists is narrowed by a temporary or permanent obstruction such as a kerb, narrowing road, stationary motor vehicle or road works.

Reservoir:
: An advanced stop line at traffic signals widened to the full width of the junction approach, so that cycles can come to the front and take up a position in the correct lane for the movement wanted.

Safety strip:
: Unused space alongside a cycle lane or track, for safety clearance.

Second Vehicle:
: The vehicle represented by a light arrow in the relevant LTSA movement code diagram (Appendix G).

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[3] Cycle width is a factor in designing obstructions to keep motor vehicles out of cycle facilities, but in practice wider vehicles can often be accommodated if on 3 or 4 wheels. Wheelchairs are excluded for this study only: some cycle facilities are specifically designed for wheelchairs (CROW, 1993, Sustrans, 1997)

2 Methodology and the LTSA database

2.1 Introduction

This section develops the methodologies used to study the available crash data and propose methods of overcoming the problems identified.

This study considers only crashes in which a cyclist is killed or seriously injured (although a broader view is taken when developing costs in Section 9), thus excluding the majority of crashes in which there is slight or no injury. This approach has three advantages.

- Minor crashes due to balancing failures or inexperience are largely excluded.
- Problems with under-reporting are by-passed so far as possible.
- Attention is focussed on the more serious incidents.

The disadvantage is comparatively few crashes to study, particularly in the less common crash types. For fatal crashes this problem is especially bad and is only partially offset by using data over a long period.

Data analysis concentrates on 14 common types of crash covering nearly 90% of injuries. The remainder fall into a total of 33 types, several of them 'catch-alls' for unclassifiable crashes, and have been ignored.

Several of the methods used here are thought to be novel, at least in a New Zealand context.

2.2 Literature search

Most recent New Zealand literature focuses on safety education, helmet wearing or cycle conspicuity (an unlovely word for bright clothing, reflective material and lights at night). The focus is on the cyclist rather than the cycling environment and so falls outside the main scope of this study.

The libraries of Lincoln and Canterbury Universities hold useful information, as do the libraries of Wellington City Council (general) and Victoria University (perception problems). The New Zealand National Library and the libraries of the LTSA and The Institution of Civil Engineers (UK) hold surprisingly little cycling information.

Earlier New Zealand studies were made by Atkinson and Hurst, who compared local data with a study in the United States (1982). Unfortunately they converted New Zealand data to the US coding system, instead of the other way round, making their work of limited use for comparison with more recent New Zealand data. Atkinson and Hurst also compared cycle crashes in two cities with a high proportion of cyclists: Christchurch and Palmerston North (1984). Other work on Christchurch data has been done by Cambridge et al (1991), including an analysis of MoT (now LTSA) crash data, field surveys of cycle numbers, helmet wearing and use of cycle routes, questionnaires of school children and adults, and a medical survey of cyclist's injuries.

A New Zealand design manual for cycle facilities was produced in 1985 (National Roads Board and Urban Transport Council, 1985).

The overseas literature is large, including the annual Velocity Conference (Perth in 1996, Barcelona in 1997) and a wide variety of other sources. Three sources in particular are well used: CROW (Netherlands, 1993), Austroads (Australia, 1993) and Sustrans (UK, 1997). These facility design manuals have already drawn on the literature available to their authors and summarise practice in their respective countries.

2.3 New Zealand crash statistics and the LTSA database

In New Zealand the LTSA keeps records of motor vehicle crashes. Data since 1980 is held on a computer database and on microfiche. The system is being updated at this study is prepared. All comments here refer to the old system, but the new system will clearly be a substantial improvement. For example there will be a copy of the investigating officer's plan available on the database, without the need to refer to aperture cards.

The database is seen by the LTSA as specifically a record of motor vehicle crashes, because the Transport Act (1962) only requires that motor vehicle crashes causing injury or death are reported to the police. This is unchanged in the Land Transport Bill introduced to Parliament in late 1997. Falls and cycle-cycle or cycle-pedestrian crashes are rarely recorded but single cycle crashes are recorded if the object struck is a parked motor vehicle.

Ideally this study should cover all crashes involving a cycle in which any person is killed or seriously injured, but the existence of unreported and non-reportable crashes are a constraint here. Begg et al (1991) investigated crashes of 13 to 15 year olds and found more cycle-cycle than cycle-motor vehicle injuries. Accident Compensation records (Table 9.2) tell a similar story. However, most injuries studied by Begg et al were minor, the worst at the level of minor concussion or a fractured wrist. In practice these crashes are not reliably recorded and are difficult to study. The approach adopted here is generally to use only crashes on the LTSA database.

The LTSA database consists of a special programme to read and manipulate data files, plus a file for each local authority. Files are heavily compressed: for example 'B' for *bright weather* and '486' for *Cyclist failed to give way when deemed turning, to non-turning or deemed non-turning traffic.* The reading software can print an expanded description, or with practice the files can be read in compressed form. The LTSA also hold a police crash report for each reported event, on microfiche. Additional information on this form includes the following.

- Names and addresses of those involved.
- A plan of the crash site.
- Witness statements.
- The investigating officer's assessment of what happened and the contributory factors, summarised in the database as a series of code numbers.

Recommendation:

- Encourage reporting of all cyclist-pedestrian and cyclist-cyclist crashes, and falls due to poor surfaces. Falls could be reported on a separate form and passed to the local authority rather than the LTSA (12).

(The number following each recommendation is the number in Appendix A)

2.4 Data selection

Most analysis in this study is based on two data sets.

- All fatal cycle crashes in the period 1980–1996: a total of 352 crashes. The period is chosen to maximise the numbers available.
- All serious injury cycle crashes in the period 1994–1996: a total of 459 crashes. The period chosen is the most recent containing a whole number of years (to eliminate seasonal bias) and with a similar number of crashes to the fatals.

These data sets are used together to identify the most common LTSA movement codes. All codes represented by 10 or more crashes in one or both of the main data sets are chosen for detailed analysis. No specific weighting is given to fatal crashes except through the periods chosen.

Several types of head-on crashes, totalling some 8% of fatal injuries, appear in the data sets but were not initially selected because numbers were just below the cut-off level. These are added as a single synthetic movement code but omitted from some comparisons because of the doubtful effects of synthesising.

2.5 Fatal crash data

The major advantage of the fatal crash data is that all or virtually all crashes are reported but there are also disadvantages.

- Numbers are small.
- The cyclist is unable to give his or her version of events.
- The data may include some suicides.

2.6 Serious injury crash data

The much larger total of serious injury crashes makes more detailed analysis possible but there are still difficulties.

- The reporting rate is low (Cambridge et al, 1993, table 51): 42% in Christchurch in 1989 and thought to be 40–50% overall. See 9.3.
- The breadth of the definition of 'serious' is very uncertain, ranging from life-threatening to minor concussion (Begg et al, 1991).
- Police assessments of injury levels may not be accurate.

2.7 Statistical analysis

Four further data sets are used for an overall statistical analysis, to allow a check for changes over time and to provide more data where needed.

- All fatal crashes in the period 1980–87. (Generally too small to be helpful).
- All fatal crashes in the period 1988–96. (Generally too small to be helpful).
- All serious injury crashes in the period 1980–87.
- All serious injury crashes in the period 1988–96.

Statistical analysis is greatly simplified by the methods used, which would give population data (a 100% sample) if all crashes were reported. It is assumed here that all fatal crashes **are** reported, and the serious injury crashes form a large sample (40–50% of reportable crashes causing injury needing medical attention) and are effectively population data.

Generalised data checks are made, looking for variations in cyclist's risk by junction type (layout and method of control), cyclist's age range and movement code, and changes over time. The comparison method used is to develop a 'Crash Frequency Index' (CFI) of the relative frequency of each type of crash, compared with crashes as a whole. This is not a standard method but has the advantage of presenting data in an easily understood form. An example is the junction comparisons in Table 3.2.

$$\text{CFI} = \frac{\text{(cycle crashes at junction type)}}{\text{(total crashes at junction type)}} \Bigg/ \frac{\text{(total cycle crashes)}}{\text{(total crashes)}}$$

The CFI is a 'ratio of ratios', comparing the ratio of cycle crashes to all road crashes at a given junction type, with the same ratio for all junctions. A CFI of 1.1 indicates that the proportion of cycle crash injuries is 10% greater than the same proportion for all junctions. CFIs are used in three cases.

- Relative risk (to cyclists compared with road users generally) by junction type (Table 3.2).
- Relative risk by movement code and cyclist age (Tables 3.5 and 3.6).
- Changes in serious injury frequency over time (Table 3.7).

Cyclist's ages are grouped into five ranges.

0–9 years	Children generally too young to cycle to school.
10–14 years	Children old enough to cycle to school in reasonably large numbers (Cambridge et al, 1991, table 33) but too young to qualify for a driving licence.
15–19 years	Young adults with good motor and perception skills but liable to excessive risk-taking.
20–59 years	Most adults.
60+ years	Elderly adults with declining skills.

In Tables 3.2 and 3.5–3.7 the more significant CFIs are shown in bold type. Significance is determined arbitrarily, by assuming that a CFI of 1.1 is significant if it represents 50 or more reported crashes, 1.2 is significant if it represents 25 or more crashes, and so on. Crash numbers are doubled for Table 3.2 (A CFI of 1.1 considered significant at 100 reported crashes etc), to draw attention to the more important figures. No more formal analysis is practicable because of the population nature of the data and its limited accuracy.

2.8 Data audit

Three sub-sets of selected crashes are audited from the LTSA's microfiche copies of the original police reports.

- Every tenth crash in the selected movement codes.
- Additional crashes in the selected movement codes to obtain a total of at least 4 fatal and 4 serious in each code, where practical with at least two crashes with the cycle as key vehicle and two with the cycle as second vehicle.
- Crashes where the coded data looks 'odd' for any reason. These are ignored when calculating the coding error rate in 3.9.

2.9 Data review

All fatal and serious injury crashes in each selected movement code are reviewed for frequently occurring features. The following features are checked for each movement code, but some features are omitted from the summaries in Appendix B where there are no or very few examples.

- Specific cyclist's faults: more than two abreast, not using a cycle way, being towed, riding on the footpath, double banking (two persons on one cycle, other than a tandem or children in specially designed seats) and wandering or wobbling.
- Cycle conspicuity problems: no or inadequate lights or dark clothing.
- Cyclist/driver inattentive etc.
- Cyclist/driver failed to give way.
- Cyclist/driver affected by alcohol (including *alcohol suspected* and a*lcohol tested but below limit*).
- Cyclist/driver too fast.
- Location: junction type, junction controlm speed limit (50 km/h and below or 70 km/h and above[4]), weather, lighting and road surface.
- Contributory factors focussed exclusively on the cyclist/driver.

A search is made of the printed listing for special features affecting each movement code 'by eye' for regularly appearing features such as cycling on the footpath in movement code JA (Table B 4). Other searches are for expected features such as tight curves or other poor visibility in movement code FA (Table B 1: in this case the expected feature is not found).

[4] The LTSA consider 70 km/h as an urban speed limit and higher speeds as rural, but this is inappropriate when cyclists are considered. See Figures 5.1 and 6.2

2.10 Cycle-friendly engineering

The second part of this study seeks methods of minimising the most common types of crash. This is done by attempting to understand the nature of the crashes and their most common causes, using methods already described, and then seeking solutions, generally from overseas practice and especially from three sources.

Austroads (1993)
: Austroads is the national association of road transport and traffic authorities in Australia, who have produced a series of manuals on road and traffic engineering practice. Part 14 covers cycle facilities.
A new edition of Austroads 14 (1998) was available in draft as this study was finalised. Differences from the 1993 edition are noted where appropriate.

CROW (1993)
: CROW is the Centre for Research and Contract Standardisation in Civil and Traffic Engineering, in the Netherlands.
CROW summarises the techniques developed in the Netherlands, with extensive research backing and practical experience. The manual is available in English.

Sustrans (1997)
: Sustrans is not an official organisation like Austroads or CROW, but a UK charitable trust. Its mana is derived from its experience in developing long distance cycle tracks, and from a UK government grant of over $100 million (NZ) for cycle facilities from the Millennium Fund. Local Authorities have to meet Sustrans requirements to obtain access to funding. Their manual draws on the CROW manual amongst other sources.

The methodology used is to compare the treatments suggested by each source for any given situation and make recommendations. During this process it is helpful to keep special features of New Zealand conditions in mind, both perceived and objective.

- Generally wide roads, with lane widths often greater than 3.5 m and rarely less than 3.0 m.
- Probably higher motor vehicle speeds than in the UK or USA—certainly higher than the Netherlands—but probably slower than in Australia, where a 60 km/h urban speed limit is general.
- New Zealand's Give-way rules.
- Generally poor driving skills.

2.11 Improvement of cycling conditions

Reviewing technical measures to improve conditions for cyclists quickly shows that the authors of the CROW manual, and to some extent the Sustrans manual, live in a different world, in which cycling is taken seriously.

Engineering proposals are useless if the political and cultural backgrounds are such that they will never be implemented, so this study also considers the thinking behind road safety in Europe, and how it compares with thinking in New Zealand. Section 9 looks at the cost of cycle crashes, Section 10 suggests changes to New Zealand law, and Section 11 looks at an alternative philosophy of road safety: road danger reduction.

2.12 Audit of road safety improvements

A preliminary check of the effect of road safety improvements is made by evaluating improvements at nine road junctions. Wellington City Council kindly supplied drawings for junctions recently improved on safety grounds (although there may also have been other reasons for improvement). The junctions were chosen by the Council. All junctions are assessed for changes to cyclist's risk as a result of the alterations, including site visits in all cases. See Table 3.11 and Appendix G.

3 New Zealand cycle crash data

3.1 Introduction

This section presents data generated from the LTSA database and census data. Detailed reviews of the selected vehicle movement codes are given in Appendix B.

3.2 Crash rate by area

Table 3.1 gives statistics for the main urban areas, from the 1991 and 1996 censuses (Statistics NZ, 1992 and 1997) and the LTSA database. The data is used to calculate the proportion of cyclists among commuters (ignoring non-travelling commuters) and the proportion of cycle injuries in the total of serious injuries, both expressed as percentages. Census data is averaged for 1988–96, using:

Average = ([1991] x 6.5 + [1996] x 2.5) / 9

Table 3.1: 1991 and 1996 census data and 1988–96 averages

Note: the cycle commuter figures for Manukau and Napier have been checked with Statistics NZ: they are a coincidence

	Working population		Cycle commuters		% change
	1991	1996	1991	1996	1991–6
North Shore	74 070	87 192	1221	978	- 20
Waitakere	60 495	72 051	828	783	- 5
Auckland	130 232	158 823	2640	2496	- 5
Manukau	87 948	105 492	1545	1176	- 24
Hamilton	42 111	49 838	2952	2841	- 4
Napier	19 938	23 229	1545	1176	-24
Palmerston N	28 818	33 246	2910	2868	- 1
Porirua	17934	18 651	141	120	- 15
Upper Hutt	16 653	17 130	657	504	- 23
Lower Hutt	41 589	44 199	984	855	- 13
Wellington	76 431	85 659	1272	1632	+ 28
Nelson	15 375	18 636	1362	1146	- 16
Christchurch	120 435	143 085	10 677	9636	- 10
Dunedin	44 571	51 240	1245	1380	+ 11
Invercargill	22 611	24 027	1215	1122	- 8

	Non-travelling commuters		Cycle crashes (serious injury)	All crashes (serious injury)	Cycles 1988–96	
	1991	1996	1988–96	1988–96	% commuters	% injuries
North Shore	10 947	14 727	52	702	1.8	7.4
Waitakere	8484	11 088	53	946	1.5	5.6
Auckland	17 067	23 367	194	2074	2.2	9.3
Manukau	11 217	14 757	89	1223	1.8	7.3
Hamilton	5370	7827	85	629	7.7	13.5
Napier	2865	3594	28	281	8.2	10.0
Palmerston N	3750	5106	60	468	11.2	12.8
Porirua	2379	2742	20	313	0.9	6.4
Upper Hutt	2106	2496	27	233	4.2	11.6
Lower Hutt	4875	6081	47	613	2.6	7.7
Wellington	8913	11 379	83	841	2.0	9.9
Nelson	2346	3090	45	354	9.6	12.7
Christchurch	16 815	22 611	340	2255	9.7	15.0
Dunedin	6396	8553	67	862	3.2	7.8
Invercargill	3108	3480	40	303	6.0	13.2
					C (x axis) in Figure 3.1	I (y axis) in Figure 3.1

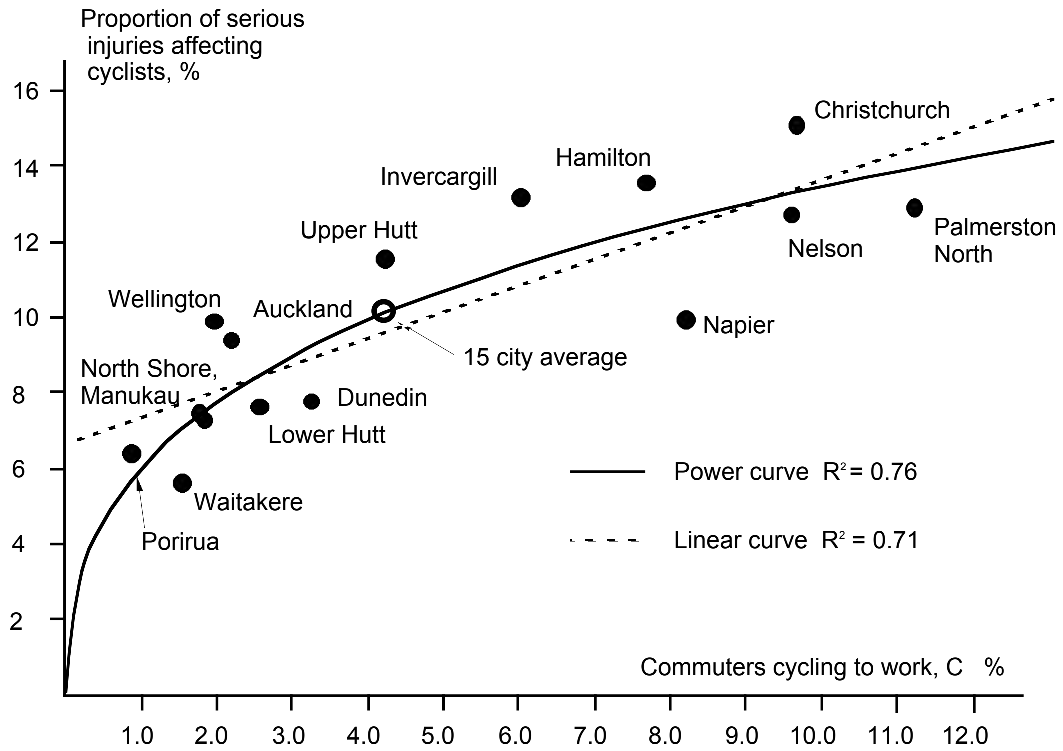


Figure 3.1: Proportion of serious injuries affecting cyclists and proportion of cyclists in commuter traffic, 1988–96

The percentages in the second part of Table 3.1 are plotted in Figure 3.1, which shows that cyclist's injuries increase with increasing numbers cycling to work, but at a lower rate. Two curves are fitted to the data but the power curve (solid line) is preferred. See 4.2:

- Power curve: $I = 6.28\ C^{0.33}$ $R^2 = 0.76$
- Linear curve: $I = 0.70\ C + 6.61$ $R^2 = 0.71$

3.3 Crash rate by junction type—fatal and serious injuries

Cyclist's risk at each type of junction is assessed by comparing the ratio of cycle crashes to all crashes at each junction type, with the same ratio for road crashes as a whole. The data sets used are the reported fatal and serious injury crashes for 1988 to 1996. Results are given in Table 3.2. The Crash Frequency Index is:

$$\text{CFI} = \frac{\text{(cycle crashes at junction type)}}{\text{(total crashes at junction type)}} \Big/ \frac{\text{(total cycle crashes)}}{\text{(total crashes)}}$$

Here the crash frequency index is the frequency of fatal or serious injuries to cyclists at the given type of junction, relative to all junctions, compared with the same ratio for all road users.

3.4 Crash frequency by movement code

Table 3.3 shows the number and percentage of cycle crashes in each movement code, for two data sets.

- Fatal crashes for the period 1980–1996.
- Serious injury crashes for the period 1994–1996.

Data is given for all movement codes where a serious or fatal cyclist injury is on one or both data sets, but other codes are omitted. The movement codes selected for further study are shown in bold in Table 3.3 and summarised in Table 3.4. The movement codes selected are those where the total in one or both data sets is at least ten. Head-on crashes are included as an additional composite movement code.

Table 3.2: Relative risk by junction type—1988–96

CFIs in bold type indicate that an arbitrary significance level has been exceeded: see 2.7.

	Cycle crashes	Total crashes	Cycles % of jn total	Jn % of cycle crashes	Jn % of all crashes	CFI
Fatal crashes						
X roads	29	351	8	17	7	**2.5**
T junction	34	591	6	20	12	**1.7**
Y junction	3	74	4	2	1	1.2
Multi-leg junction	1	28	4	1	1	1.1
Roundabout	2	19	11	1	<1	**3.2**
Driveway	24	204	12	14	4	**3.5**
No junction	73	3715	2	44	75	**0.6**
Totals, averages	166	4982	3.3%	100%	100%	1.0
Traffic signals	21	263	8	23	21	1.1
Give Way	38	630	6	41	50	0.8
Stop	16	309	5	17	24	0.7
No control*	18	65	28	19	5	**3.8**
Totals, averages	93	1267	7.3%	100%	100%	1.0
Serious crashes						
X roads	364	3343	11	19	13	**1.5**
T junction	569	5070	11	30	20	**1.5**
Y junction	40	511	8	2	2	1.1
Multi-leg junction	23	195	12	1	1	**1.6**
Roundabout	71	326	22	4	1	**2.9**
Driveway	302	2106	14	16	8	**1.9**
No junction	544	14278	4	28	55	0.5
Totals, averages	1913	25 833	7.4%	100%	100%	1.0
Traffic signals	157	1443	12	12	13	**0.9**
Give Way	396	2908	14	31	26	**1.2**
Stop	130	1272	10	10	11	**0.9**
No control*	615	5676	11	47	51	0.9
Totals, averages	1298	11 229	10.8%	100%	100%	1.0

* Calculated by difference, including driveways. No separate estimate is possible because crashes not involving any junction may be recorded this way.

Table 3.3 Frequency of injuries by vehicle movement codes

Codes are omitted where no cycle crashes have been recorded

		Fatal injury 1980–96		Serious injury 1994–96	
		Number	%	Number	%
A	**Overtaking and lane change**				
AA	**Pulling out or changing lane to right**	**16**	**5**	**23**	**5**
AB	**Pulling out or lane change—head on***	**7**	**2**	**4**	**1**
AC	**Cutting in or changing lane to right**	**12**	**3**	**9**	**2**
AD	Lost control (overtaking vehicle)	1	-	2	-
AE	Side road	1	-	-	-
AF	**Lost control (overtaken vehicle)**	**11**	**3**	**8**	**2**
AG	Weaving in heavy traffic	-	-	2	-
AO	Other	1	-	-	-

* Grouped as a single movement code

Continued on next page

Table 3.3 continued: Frequency of injuries by vehicle movement codes

		Fatal injury 1980–96		Serious injury 1994–96	
		Number	%	Number	%
B Head on					
BA	**On straight***	**7**	**2**	**3**	**-**
BB	**Cutting corner***	**2**	**-**	**9**	**2**
BC	**Swinging wide***	**7**	**2**	**9**	**2**
BD	**Both or unknown***	**-**	**-**	**2**	**-**
BE	**Lost control on straight or curve***	**5**	**1**	**3**	**-**
BO	Other	1	-	-	-
* Grouped as a single movement code					
C Lost control or off road (straight roads)					
CA	Out of control on roadway	1	-	1	-
CB	Off roadway to left	-	-	1	-
CC	Off roadway to right	1	-	1	-
D Cornering					
DA	Lost control turning right	2	-	-	-
DB	Lost control turning left	1	-	1	-
E Collision with obstruction					
EA	**Hit parked vehicle**	**11**	**3**	**35**	**8**
EB	Accident or broken down	2	-	1	-
F Rear end					
FA	**Rear end of slow vehicle**	**73**	**21**	**37**	**8**
FE	Signals	1	-	1	-
FF	Other	-	-	1	-
FO	Other	1	-	1	-
G Turning versus same direction					
GA	Rear of left turning vehicle	2	-	2	-
GB	**Left side side swipe**	**17**	**5**	**13**	**3**
GC	**Stopped or turning from left side**	**24**	**7**	**18**	**4**
GD	Near centre line	2	-	1	-
GE	Overtaking vehicle	7	2	9	2
GF	Two turning	-	-	2	-
GO	Other	2	-	-	-
H Crossing (no turns)					
HA	**Right angle crossing, no turns**	**25**	**7**	**63**	**14**
J Crossing (vehicle turning)					
JA	**Right turn, right side**	**33**	**9**	**57**	**12**
JC	Two turning	-	-	3	-
JD	Left turn, left side	2	-	-	-
JO	Other	7	2	-	2

Continued on next page

Table 3.3 continued: Frequency of injuries by vehicle movement codes

		Fatal injury 1980–96		Serious injury 1994–96	
		Number	%	Number	%
K Merging					
KA	**Left turn in**	**10**	**3**	**17**	**4**
KB	**Right turn in**	**11**	**3**	**14**	**3**
KC	Two turning	-	-	1	-
L Right turn against					
LA	Stopped, waiting to turn	-	-	1	-
LB	**Making turn**	**27**	**8**	**74**	**16**
LO	Other	-	-	1	-
M Manoeuvring					
MA	Parking or leaving	-	-	5	1
MB	**U turn**	**9**	**3**	**11**	**2**
MC	Reversing along road	2	-	1	-
MD	Driveway manoeuvre*	3	1	6	1
MO	Other	-	-	2	-
N Pedestrians crossing road					
NA	Left side	2	-	1	-
P Pedestrians other					
PA	Walking with traffic	1	-	-	-
Q Miscellaneous					
QG	Trailer or load	-	-	1	-
QO	Other	2	-	-	-
	Selected subtotal – excluding head-ons	**279**	**72**	**379**	**83**
	Selected subtotal – including head-ons	**307**	**88**	**407†**	**89**
	Total	**352**	**100**	**459**	**100**

* Most driveway crashes are recorded in other codes.
† The total for the selected serious injury crashes is not quite correct because two head-on crashes were missing from the database copy used and were not pursued.

Table 3.4 Frequency of injuries by selected movement codes

In diminishing order of the total number of crashes (head-on shown separately)

		Fatal 1980–96		Serious injury 1994–6	
		Number	% of total	Number	% of total
FA	Rear end of slow vehicle	73	21	37	8
LB	Right turn against	27	8	74	16
HA	Right angle crossing, no turns	25	7	63	14
JA	Crossing vehicle turning right	33	9	57	12
EA	Hit parked vehicle	11	3	35	8
AA	Pulling out or changing lane to right	16	5	23	5
GC	Stopped or turning from left side	24	7	18	4
GB	Side swipe to left side	17	5	13	3
KA	Left turn in	10	3	17	4
KB	Right turn in	11	3	14	3
MB	U turn	9	3	11	2
AC	Cutting in or changing lane to left	12	3	9	2
AF	Lost control (overtaken vehicle)	11	3	8	2
B (all except BO) + AB	Head-on	28	8	28	6
Totals					
	– selected excluding head-ons	279	79	379	83
	– head-ons	28	8	28	6
	– other	45	13	52	11
Grand total		352	100	459	100

3.5 Injury frequency by cyclist's age

Tables 3.5 and 3.6 show injury frequency by age range for the selected vehicle movement codes. Table 3.5 looks at fatal injuries: numbers are too small for a proper analysis but are the best available. Table 3.6 takes this analysis further with a larger database, using serious injuries for the period 1988–96.

In both cases, results are presented as totals and as a CFI, calculated as:

$$\frac{\text{(cycle crashes in age group and movement code)}}{\text{(total cycle crashes in movement code)}} \Big/ \frac{\text{(total cycle crashes in age group)}}{\text{(total cycle crashes)}}$$

In this case a CFI of 1.1 indicates that injuries are happening at a rate 10% greater than could be expected if no age effects were present.

Note that in some crashes the age is given as 'unknown'; these are omitted from Tables 3.5 and 3.6.

Table 3.5: Fatal injury frequency by age range and movement code —1980–96

Highlighted figures indicate an arbitrary significance level : see 2.7

	Age (years)	0–9		10–14		15–19		20–59		60+	
		No	CFI	No	CFI	No	CFI	No	CFI	No	CFI
	Vehicle movement code										
FA	Rear end of slow vehicle	2	0.3	9	**0.6**	13	1.2	41	**1.5**	8	1.1
LB	Right turn against	4	0.9	8	1.4	2	0.5	12	1.2	1	0.4
HA	Right angle crossing, no turns	8	**1.9**	4	0.8	1	0.3	7	0.8	5	**2.0**
JA	Crossing vehicle turning right	10	**1.8**	7	1.0	6	1.2	8	0.6	2	0.6
	Other codes omitted due to small numbers										
Totals		58		72		52		134		36	
Grand total		352									

Table 3.6 Serious injury frequency by age range and movement code —1988–96

Highlighted figures indicate an arbitrary significance level : see 2.7

	Age (years)	0–9		10–14		15–19		20–59		60+	
		No	CFI	No	CFI	No	CFI	No	CFI	No	CFI
	Vehicle movement code										
FA	Rear end of slow vehicle	11	0.7	13	**0.4**	22	0.9	77	**1.5**	5	1.1
LB	Right turn against	28	**0.7**	67	**0.9**	55	**0.9**	158	**1.2**	6	0.5
HA	Right angle crossing, no turns	36	1.1	66	1.0	57	**1.1**	94	**0.9**	11	1.1
JA	Crossing vehicle turning right	44	**1.4**	61	1.0	43	0.9	97	1.0	6	0.7
EA	Hit parked vehicle	5	0.3	18	**0.6**	50	**1.8**	64	**1.1**	2	0.4
AA	Pulling out or changing lane to R	15	1.2	37	**1.5**	15	0.8	26	**0.6**	8	**2.2**
GC	Stopped or turning from left side	11	1.0	37	**1.9**	17	1.0	14	**0.4**	5	1.6
GB	Side swipe to left side	3	0.5	11	0.9	12	1.1	24	1.1	3	1.5
KA	Left turn in	4	0.6	11	0.8	18	**1.6**	21	0.9	3	1.4
KB	Right turn in	11	**2.1**	11	1.1	11	1.3	7	0.4	2	1.3
MB	U-turn	13	**1.6**	18	1.2	10	0.8	18	**0.7**	5	**2.1**
AC	Cutting in or changing lane to left	2	0.5	4	0.5	5	0.7	20	**1.5**	3	2.4
AF	Lost control (overtaken vehicle)	2	0.5	11	1.3	1	0.1	17	1.2	4	**3.1**
B (all except BO) + AB Head-ons		3		6		3		15		-	
Codes not selected		53	1.2	89	1.1	62	0.9	136	1.0	7	0.6
All injury crashes		238		454		378		773		70	

3.6 Change in serious injury frequency over time, by selected codes

The selected codes are checked for changes in relative frequency over time, using serious injuries 1980–87 and 1988–96. Results are presented in Table 3.7. In this case the crash frequency index is:

$$\frac{\text{(Cycle crashes in movement code, 88–96)}}{\text{(Total cycle crashes 88–96)}} \bigg/ \frac{\text{(Cycle crashes in movement code, 80–87)}}{\text{(Total cycle crashes 80–87)}}$$

Here a CFI of 1.1 indicates that the relative frequency of the given crash type increased by 10% between 1980–87 and 1988–96. Again, highlighted figures indicate the more significant figures.

3.7 Bus-cycle conflicts

I was advised that bus-cycle conflicts needed checking, which seemed to be confirmed by observation while using buses in Christchurch in 1997. Further apparent confirmation is that Ringer (1994) advises touring cyclists to *Watch out also for suburban buses. The drivers have a nasty habit of pulling out from stops without noticing passing cyclists.* However, few buses show up in the cycle crash data, so the bus data is checked for cycles. See Table 3.8.

Table 3.7 Change in serious injury frequency over time, 1980–87 to 1988–96

Highlighted figures indicate an arbitrary significance level : see 2.7

Vehicle movement code		Cycle crashes 1980–87	Cycle crashes 1988–96	CFI
FA	Rear end of slow vehicle	187	128	**0.8**
LB	Right turn against	398	314	0.9
HA	Right angle crossing, no turns	259	264	**1.2**
JA	Crossing vehicle turning right	259	251	1.1
EA	Hit parked vehicle	137	139	**1.2**
AA	Pulling out or changing lane to right	38	101	**3.0**
GC	Stopped or turning from left side	168	84	**0.6**
GB	Side swipe to left side	45	53	1.3
KA	Left turn in	72	57	0.9
KB	Right turn in	51	42	0.9
MB	U-turn	77	64	1.0
AC	Cutting in or changing lane to left	22	34	**1.8**
AF	Lost control (overtaken vehicle)	31	35	1.3
B (all except BO) + AB Head-ons		119	100	
Codes not selected		331	247	0.9
Totals, average		2194	1913	1.00

Table 3.8: Serious and minor injury crashes involving a bus and a cycle, 1988–96

Auckland	AC, HA(2), MB, QB†, AG	Manukau City	AA
		North Shore City	LB
Christchurch	AF, EA, GF, LB	Western Bay of Plenty	JA
Hutt City	HA	Wellington	DB
Manawatu District	JA		

Minor injury crashes involving a bus and a cycle, 1988–96 (Christchurch only)
AA, AC(2), AF(2), AO, EA, FA, FD†, GE, JA, LB, MA, MC

†These movement codes are omitted from Table 3.3 because no crashes appeared in that data set

3.8 Roundabouts

Roundabouts are a well known hazard for cyclists so a check is made of the vehicle movement codes to be expected. Roundabouts crashes in the selected data are listed in Table 3.9.

Table 3.9: Cycle crash movement codes at roundabouts

Serious injury crashes at roundabouts, 1994–96

AC	AF	CB	GA	GB	GF	HA	JA	JC	KB	KC	LB
						(12)					(5)

Fatal injury crashes at roundabouts, 1980–96

AC				GB

3.9 Audit of microfiche reports

A sample of the selected crashes is reviewed from the police reports held at LTSA head office. See Appendix C. The accuracy of the results is summarised in Table 3.10.

Table 3.10: Audit summary of LTSA microfiche records

	Ten percent sample (T)		Ten percent sample plus additional sample (T + A)	
	No	%	No	%
Total	73		127	
Movement code wrong	7	10	15	12
Movement code possibly or probably wrong	7	10	14	11
Cause code wrong	9	12	10	8
Cause code possibly or probably wrong	2	3	2	2
Card not found	5	7	8	6

3.10 Audit of road safety improvements

An audit of safety improvements at 9 junctions is made. See Appendix D, which is summarised in Table 3.11.

Table 3.11: Audit of cycle safety changes due to junction alterations

Junction	Description	Safety changes for cyclists
1	Traffic island etc on T junction, suburban	Safer
2	Roundabout with core and collar, suburban	Substantially more dangerous
3	Mini-roundabout with drive-over core, suburban	Substantially more dangerous
4	Signalised T junction with slip road, urban	Substantially more dangerous
5	T junction on minor road, urban	Slightly safer
6	Signalised Y junction, urban	More dangerous
7	Pedestrian crossing in suburban shopping centre	Slightly more dangerous
8	T junction with turning traffic, suburban	Slightly safer
9	Busy signalised crossroad, urban	Slightly more dangerous

4 Discussion of Crash Data

4.1 Introduction

This section presents discussion on the cycle crash data in Section 3.

The accuracy of the audited Traffic Accident Reports (Table 3.10 and Appendix C) is disappointing, throwing doubt on the accuracy of derived information.

4.2 Crash rate by area

Figure 3.1 plots the percentage of full time workers cycling to work, against the percentage of cyclists involved in serious injury crashes, for 1988–96. Four curves have been fitted to the data: two of them are plotted in Figure 3.1 (I= Injuries, C = Commuters):

Power curve (solid line in Figure 3.1):

$I = 6.28\ C^{0.33}$ $R^2 = 0.76$

This curve has an equal best regression coefficient and is preferred.

Linear curve (broken line in Figure 3.1):

$I = 0.70\ C + 6.61$ $R^2 = 0.71$

The curve is quite a good fit to the data but has a lower regression coefficient than the power curve and an unrealistic boundary condition. If cyclists were driven off New Zealand roads, the last cyclist could expect to face high risks but not 6% of all serious injuries: two crashes a day. Despite this difficulty, the linear curve is used to give a conservative extrapolation to higher cycle numbers.

Logarithmic curve (not plotted):

$I = 3.18 \ln C + 5.91$ $R^2 = 0.76$

This curve has the same regression coefficient as the power curve and is equally acceptable for the range of plotted data. However, it is less conservative at commuter cycle numbers above 10% and so is ignored.

Exponential curve (not plotted): $R^2 = 0.69$

Ignored because of a low regression coefficient.

Correlation coefficients are surprisingly high, given that the proportion of serious injuries involving cyclists is for all cycle crashes but the cycle numbers are for travel to full-time work only, excluding students, utility and recreational cyclists. This suggests that census data on commuters is a reasonably reliable indicator of cycle numbers.

Replotting and extrapolating the curves in Figure 3.1 shows that individual cyclist's risk falls substantially as cycle numbers increase but—surprisingly—the choice of curve makes little difference. See Figure 4.1. Risk is here defined arbitrarily as 100 units at the point where the linear and power curves in Figure 3.1 first cross: C = 2.2%, I = 8.15%. The equation used for the curves in Figure 4.1 is:

Individual risk =

$$\frac{I}{C} \times \frac{100}{3.7}$$

(3.7 = I/C at the point where y = 100 units. I and C are calculated using the first two equations above)

The chosen origin of 100 arbitrary units is close to the plotted values for Auckland, North Shore, Manukau and Lower Hutt. On this scale individual cyclists face predicted risks of 180 units in Porirua and 34 units in Palmerston North. When Christchurch City Council achieve their target of 20% of commuters on cycles (Christchurch CC, 1996), they can expect an individual cyclist's risk of 25 units, compared with 37 units in 1988–96.

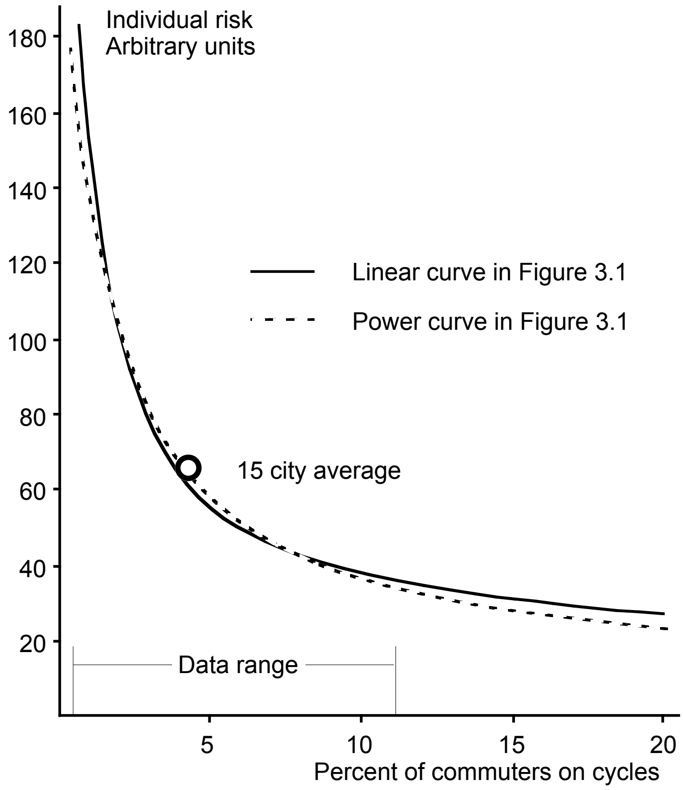


Figure 4.1: Individual cyclists' risk

Unfortunately the information in Cambridge et al (1991) and MoT (1992) is not quite sufficient for calibrating the risk axis in Figure 4.1.

Figure 4.1 suggests that increasing national cycle numbers to the suggested target of 16 % of commuters (see 5.7) will reduce the average individual cyclist's risk to about 26 units, or 40% of the present average of 66 units for the 15 cities in Figure 3.1.

Slopes for the power curve in Figure 3.1 range from 0.35 for Porirua to 0.07 for Palmerston North. This suggests that in Porirua any increase in cycle numbers will be some three times greater than the increase in crash numbers, so the marginal cost of cycle safety is only a third of the average cost. In Palmerston North more of the potential benefits of cycle numbers have been realised, and marginal cost is 93% of average cost. The explanation is probably that cyclists in Palmerston North have become more 'expected' by other road users due to greater numbers. The Royal Commission on Environmental Pollution (1994, p 54) says that:

> *The evidence from the continent is that increased cycle use can lead to a lower risk because cyclists are less easily overlooked by motorists, and road layouts are increasingly designed with the safety of cyclists in mind.*

The marginal safety cost of car use is also lower than average cost (West-Oram, 1991, p 359), but closer to the average than for cycles. The annual average growth in vehicle kilometres for 1976–96 (MoT 1997b, figure 6.7) was 3.0%, and the annual reduction in total fatalities between 1975–77 and 1995–97 was 0.9% (LTSA database: three year averages are used to stabilise the numbers). Even assuming that the whole of this reduction is due to additional vehicles, the marginal cost of a new trip is only 99.1/103 percent of the average cost, or 96%. This is much less than local variations in the average (LTSA, 1996) and can be ignored.

Taking a broader view, the marginal cost of car use in a congested area is very high, because of congestion and pollution, but remains low for cycles because of the cyclist's ability to slip through congested traffic (Fietsersbond, 1997).

Increasing cycle numbers means lower cycling risk but this begs the question of why the increase? If there are more cyclists because cycle facilities are safer then the argument is circular. Another possibility is that the number of cyclists is independent of the quality of facilities. The most likely answer is that both effects are present but that cycle numbers are dominant, as discussed in 8.5: the argument is only slightly circular. (In this context it is irrelevant whether facilities are formally designed for cyclists or simply happen to be safer.)

Summarising, the marginal cost of cyclist's risk is below average cost, and the difference falls as cycle numbers increase. More cyclists will reduce cycling risk.

Recommendations:

- Investigate the relative safety risks of additional trips by cycle and motor vehicle, for high risk and average risk road users, and for cities with high and low cycle use (66).
- Set a target of reducing the cycling fatality rate to no more than 20 per billion kilometres cycled by 2008 (1).
  (This recommendation comes from the UK Royal Commission on Environmental Pollution (1994). The time scale has been increased from 6 years to 10, to cover a greater reduction needed in New Zealand)

4.3 Risk by junction type

Relative risk by junction type is given in Table 3.2 for both fatal and serious injury crashes. However, the fatal injury data is of limited use because of small numbers and is useless for the less frequent crash types. Several conclusions can still be drawn from Table 3.2.

- Junctions are relatively more dangerous for cyclists than for other road users.
- Roundabouts are known to be a special problem for cyclists but driveways and crossroads are also problem areas, especially for fatal injury crashes.
- Uncontrolled intersections seem to be particularly bad for fatal crashes. However, the data is doubtful here because numbers are obtained by difference.
- Junctions with 'Stop' control are relatively safe.

Recommendation:

- Prefer junctions controlled by 'Stop' signs for cycle safety (32).

4.4 Injury rates by cyclist's age

Relative injury frequency by cyclist's age is given in Tables 3.5 and 3.6. Fatal crashes (Table 3.5) are usually too few to give a reasonable breakdown. Serious injury numbers (1988–96: Table 3.6) are more reliable but the risks for fatal and serious injures may differ. For example turning motor traffic is less likely to cause fatal cyclist injuries than straight-through traffic because speeds are lower.

- The 0–9 years age group is relatively badly affected by fatal crashes in movement codes HA and JA, mainly at driveways. For serious injury crashes they have more trouble with movement codes JA, KB and MB.
- The 10–14 years age group has little trouble with being hit from behind (FA). They are badly affected by serious injuries in movement codes AA and GC, this and personal observation suggests that the age group is tending to ride too far to the left and to stay on the left for too long when turning right. They hit parked vehicles (EA) comparatively rarely.
- The 15–19 years age group has more trouble with hitting parked vehicles (FA), and left turns in (KA). This seems to suggest over-confidence.
- The 20–59 years age group is badly affected by movement codes FA and LB (rear end and right turn against) for both fatal and serious injury crashes. They also suffer most of the serious injuries from code AC, mostly as second vehicle, which suggests crowding. In movement code LB (right turn) this group is much more likely to be the key vehicle than other age groups.
- The 60+ age group has more trouble with codes AA, AF and MB but numbers are too small to draw firm conclusions. The movement codes suggest trouble with turning right and crowding.

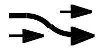
4.5 Changes in injury frequency over time

Variations in serious injury crash rates over time are shown in Table 3.7. The comparison is between 1980–87 and 1988–96. Fatal crashes cannot be compared because of small numbers.

- The largest change is in pulling out or changing lane to the right (AA), with a threefold increase in relative frequency. This code seems likely to break down into three sub-groups for cyclists.
  - Starting a right turn.
  - Starting off from a driveway etc but travelling more than 20 m from the junction and so not coded as KA.
  - Pulling out to clear a parked car or other roadside obstruction.

  The first manoeuvre is very similar to movement code GC: stopped or turning from left side, which has had a large drop in numbers, so one explanation is that the same type of incident used to be coded GC but is now more often coded AA[5].
- Movement codes AC and AF show large increases over time and are similar to each other and to some crashes of movement code AA. All of these are overtaking or lane change crashes, or both.

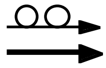
  AA: Pulling out or changing lane to right. Cycle mainly key vehicle

  AC: Cutting in or changing lane to left. Cycle mainly 2nd vehicle.

  AF: Lost control (overtaken vehicle). Cycle predominantly 2nd vehicle.

- There have been small increases in the frequency of right angle crossing crashes (HA) and hitting parked cars (EA). No explanation has been found.

4.6 Crash type FA: Rear end of slow vehicle

See Table B.1 (Appendix B) for a summary of crash data extracted from the LTSA database.

Crash type FA is the worst for fatal crashes, accounting for 21% of all cycle fatalities. It tends to be typified as happening on a bend, at night, on a rural road, to a cyclist with no tail light, but of 73 cyclists killed:

- 72 were hit on a straight road or an easy curve
- 66 were not cited as wandering or wobbling
- 65 were hit by a driver who was not cited as speeding
- 59 were hit in good weather
- 49 had adequate lights or were reasonably visible by day (ie contributory factor codes did not include 407, 931, 932 or 935, see 4.20)
- 49 were hit by a driver who was not cited as affected by alcohol or drugs
- 35 were hit in daylight
- 24 were hit in a 50 km/h speed limit area.

Cyclists fear this crash type most. In New Zealand these fears are justified despite the comments of Forester (1994) and Franklin (1997). Franklin says of the UK:

> *Many cyclists... dread riding in close proximity to other traffic, because of the fear of being hit from behind. In fact, this type of collision is one of the least likely, accounting for no more than 5% of cycle-car casualties—and many of these are as a result of the cyclist swerving carelessly into traffic.*

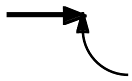
I conclude that the UK equivalent of movement codes FA and AA together account for 5% of cycle casualties, but in New Zealand the total is 25% of

[5] Thanks to Tim Hughes, LTSA Christchurch Office, for this suggestion

fatal crashes and 13% of serious injury crashes (Table 3.5).

This movement code is the only important case where the work of Atkinson and Hurst (1982) can be directly compared with more recent data. Being hit from behind was an even bigger problem in their study, accounting for 33% of fatalities. It seems to be mainly a driver education or perception problem. Speeding is not specially cited but is likely to be a factor.

4.7 Crash type LB: Right turn against



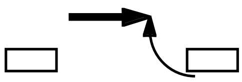
See Table B.2 for a summary of crash data extracted from the LTSA database.

Fatal crashes are evenly split between the cycle as key vehicle (bold arrow) and second vehicle, but the cycle is key vehicle in some two thirds of serious injury crashes. Cyclists aged 15–59 are more likely to be key vehicle. This movement code can be broken down into several possible scenarios.

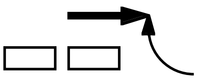
a) Cycle key vehicle, seen but speed misjudged by the driver.

b) Cycle key vehicle, not seen by the driver due to either conspicuity or driver factors.

c) Cycle key vehicle, hidden from the driver by oncoming vehicles overtaking the cyclist.



d) Cycle second vehicle, driver hidden by other motor vehicles waiting to turn right.

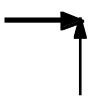


e) Other factors, including cycle falls.

Possible measures to reduce the risk of these types include the following.

- Reduce speeds at junctions. This will reduce the risk of most scenarios.
- Educate drivers to be aware of cyclist's very variable speeds (scenario a).
- Educate drivers to look out for cyclists, particularly in scenario (c).

4.8 Crash type HA: Right angle crossing, no turns

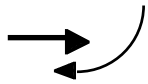


See Table B.3 for a summary of crash data extracted from the LTSA database.

The cyclist is slightly more likely to be the second vehicle, for both fatal and serious injury crashes. The cyclist's age range is wide, with the 0–9 and 60 + age groups particularly at risk. The frequency of this type of crash has increased since 1980–87. A high proportion of crashes are at Give Way controlled junctions.

Speed reduction will obviously help with all this, but another real problem is that children do not have the necessary skills. See 11.3.

4.9 Crash type JA: Crossing vehicle turning right



See Table B.4 for a summary of crash data extracted from the LTSA database.

All fatal crashes and about 60% of serious injury crashes have the cycle as second vehicle, turning right from the driver's left. The difference will be due to lower motor vehicle speeds when turning. Young cyclists turning right are very vulnerable.

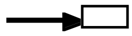
The ten fatal injury crashes involving cyclists aged 0–9 were in speed limit areas of 50 km/h (7), 70 km/h, 80 km/h and 100 km/h. The contributory factors cited are listed in Table 4.1. One factor is conspicuous by its absence: there is no suggestion that any driver was going too fast, despite 6 cases of adverse visibility. Again, the problems seem to be speed and children's lack of ability.

Table 4.1: Contributory factors to movement code JA causing fatal injuries, age 0–9 years

Ten crashes, cyclist second vehicle in all cases

Code	Description	Citings
102	Driver alcohol test below limit	2
320	Cyclist failed to give way	2
328	Cyclist failed to give way at driveway	2
420	Cyclist did not check	1
422	Cyclist did not check when pulling out from side of road	2
450	Cyclist inattentive	1
487	Cyclist turning, failed to give way to non-turning or deemed non-turning traffic	4
489	Cyclist failed to give way to traffic approaching or crossing from right	2
834	Visibility limited—trees	1
835	Visibility limited—hedge or fence	1
838	Visibility limited—dust or smoke	1
901	Heavy rain	1
902	Dazzling sun	2
933	Cycle brakes defective or failure	1
975	Cycle leaving commercial entrance	1
977	Cycle leaving private drive	2

4.10 Crash type EA: Hit parked vehicle



See Table B.5 for a summary of crash data extracted from the LTSA database.

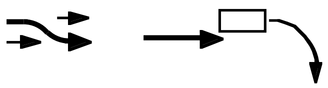
In two fatal crashes the vehicle hit was a cycle, but in all other cases the cycle was key vehicle. The relative frequency has increased since 1980–87.

Cyclists do sometimes hit parked cars. I have done it (lost control on a wet road) and two cyclist friends tell me they have done something similar. However embarrassing these events may be, they are usually minor, despite one clear and fatal case in the audit of crashes (Appendix C: 88/00282). Other likely scenarios are given below.

- A car door opened into the cyclist's path. In the crashes studied, some 30% of fatal and 40% of serious injury crashes were caused this way. Cambridge et al (1991) assign this cause to half of serious injury crashes involving adults.
- The cyclist lost control because of poor road surface etc or crowding by a motor vehicle. Anecdotal evidence is that these are important causes but they are not cited in any of the crash reports studied. See 4.18.
- Other factors, including a cyclist fatally involved when a car hit a stock trailer (no cyclist details given), and a crash during an approved cycle race.

It is difficult to know what to suggest here, except greater separation of cycles from motor traffic and greater care by cyclists. However, see the comments by Brown in 4.20.

4.11 Crash types AA and GC: Pulling out or changing lane to right, and Stopped or turning from left side



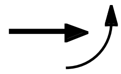
See Tables B.6 and B.7 for summaries of crash data extracted from the LTSA database. In most cases the cycle is turning, key vehicle for movement code AA and second vehicle for code GC. The serious injury crashes show a bias towards younger and elderly cyclists (0–14 and 60+). Serious injury numbers have risen very substantially since 1980–87 but this is probably a change in coding practice. See 4.5.

The following scenarios are possible.

- Cyclist turning right. The coded summaries do not show intentions—inevitably—and numbers are unknown, but my impression is that this is the main cause.
- Cyclist pulling out to pass a parked car or avoid a pothole etc. Cited once in the crashes studied.
- Driver factors, cited in only 4 of the crashes studied.
- Other factors, such as two cases where a strong wind was cited.

The predominant problem seems to be cyclists having difficulty in turning right, plus driver factors.

4.12 Crash type GB: Side swipe to left



See Table B.8 for a summary of crash data extracted from the LTSA database.

The cycle is key vehicle in most cases, sideswiping or being hit or crowded by a motor vehicle turning from the cyclist's right. Most fatal injuries are in crashes involving a truck (12 out of 15, but only 3 out of 13 for serious injuries), often at a private entrance.

Possible scenarios include the following.

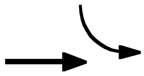
- A driver leaving insufficient space to overtake a cycle before turning left, possibly because of misjudging the cyclist's speed.
- A cyclist attempting to overtake a motor vehicle on the left and crushed when the vehicle turns left.
- A cyclist riding on the footpath and hit by a turning vehicle. There are 4 such cases in the fatal crashes studied, two of them at private entrances.
- Other factors, such as a cycle overtaking a truck and hitting a traffic island, or a driver interfered with by a passenger.

The main problem is trucks turning left. The audited cases include a serious injury crash where a cyclist saw a truck signal but assumed that the turn would be later than it was. In the audited cases it is very difficult to tell what were the cyclist's intentions.

Anecdotal evidence suggests that the first scenario is very common, and is connected with the very variable speed of cyclists (see 1.4). Other scenarios are areas for cyclists' improvement, although cyclists riding on the footpath is an indicator of difficulty or danger in riding on the road.

Fencing between road and footpathis common in the UK and beginning to appear in New Zealand. It is dangerous for cyclists because it leaves no escape route, particularly on left turns or bends.

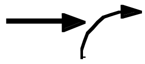
4.13 Crash type KA : Left turn in



See Table B.9 for a summary of crash data extracted from the LTSA database.

The cycle is second vehicle in most fatal and about half the serious injury crashes; the difference is probably motor vehicle speed at impact. Many crashes are at driveways or T junctions and almost all are in urban areas. The audited crashes show too much miscoding: mainly confusion with movement code HA.

4.14 Crash Type KB: Right turn in



See Table B.10 for a summary of crash data extracted from the LTSA database.

All the fatal crashes have the cycle as second vehicle and almost all are in urban areas. Nine of 11 fatally injured cyclists were aged under 15 or over 60. Again, the audited crashes show too much miscoding: mainly confusion with movement code HA.

4.15 Minor crash types

See Tables B.11 to B.14 for a summary of crash data extracted from the LTSA database.

- In crash type MB (U-turn) there is a strong bias towards younger and elderly cyclists. Again, a turning motor vehicle is less likely to inflict fatal injuries.
- In crash types AC and AF (cutting in or changing lane to the left, and lost control—overtaken vehicle) the cycle is usually the second (overtaken) vehicle. Elderly cyclists seem most at risk but numbers are small.
- The head-on crash types have a wide range of causes with no clear pattern. Cyclist factors range from a foot slipping off a pedal to carrying a boogie board.

4.16 Buses

Data on bus-cycle conflicts is given in 3.7. They are not a major problem, with only about 2 serious injury cases a year in New Zealand. These conflicts can seem more important than they are because a bus and a cycle tend to travel at roughly the same average speed. A conflict at one stop may lead to a 'tortoise and hare' sequence at one or more following stops. However, few bus-cycle crashes are of movement codes AA, AC, AD or EA, which is what would be expected with stop conflicts.

Recommendation:

- Combined bus-cycle lanes are acceptable unless bus or cycle traffic is very heavy or bus speeds are high (33).

4.17 Roundabouts

Data on roundabout crashes is given in 3.8. In New Zealand 11% of all roundabout fatalities are cyclists, for a mode that accounts for only 1.1% of vehicle kilometres (MoT, 1992). The figure for serious injuries is 22%. Cyclists are 20 times more likely than other road users to be injured at a roundabout, or more like 50–100 times allowing for unreported crashes and cyclists avoiding roundabouts: Watkins (1984) found, in the UK, that 28% of predominantly experienced cyclists took action to avoid a roundabout on their regular journey.
A recommendation is made in 7.9.

4.18 Comparison with Christchurch cycle survey

Cambridge et al (1991, table 31) surveyed the crash experience of cyclists in Christchurch. Serious injuries to adults are used here, but percentages from the children's survey (ages 10–18) are also given. In Table 4.2 the contributing factors reported are used to develop an expected total of contributing factors for serious injury crashes in this study. In the Christchurch survey the contributing factors totalled 140% (because of multiple factors) so in this study the contributing factors given should theoretically total 140% of the 379 serious injury crashes studied (head-ons excluded), or 531 factors. The survey is of course subjective, and useless for studying contributory factors due to the cyclists.

Points to note are given below.

- The number of cyclists who simply lost control is much larger than in the LTSA database.
- The number of drivers recorded in the database as failing to give way is only about two thirds of the expected total of drivers who *failed to see the cycle in time,* although the totals are more comparable if it is assumed that other crash causes are involved.
- *Crowded by motor vehicle* is not defined in Cambridge et al (1991), but I have attempted a definition in 1.7. It does not appear in the LTSA coding system but can sometimes be inferred from movement codes of type A with the cycle as second vehicle. However, the total of these movements is only half the total of cyclists crowded in the Christchurch survey.

- From the Christchurch survey a total of 42 serious injuries due to loose gravel and 22 injuries due to a poor road surface can be expected in this study, but none are recorded in the crashes seen.

Crashes due to crowding by a motor vehicle and road surface problems appear to be heavily under-reported in the database.

Recommendations

- Maintain a smooth surface at the road edges, where cyclists ride (63).
- Specifically record and investigate crashes where a cyclist was crowded (13).

4.19 Cycling stress indicators

Official figures need cautious interpretation when planning cycle facilities. McClintock (1992, p 80) says:

> *Rather than simply condemn all signs of* [cyclist's] *non-compliance with the traffic rules it is essential that traffic planners study these clues for the very useful evidence they can yield of cyclist's desire lines, on the one hand, and on the other, of areas they avoid as being too dangerous. Such behaviour may also reveal evidence of poor design, encouraging conflicts rather than making them less likely.*

Factors in the LTSA database which could indicate problems are listed in Table 4.3. Obviously some of these factors may indicate other things than safety problems for cyclists, but more careful recording of these factors should help engineers to design more appropriate cycle facilities.

Table 4.2 Comparison with Christchurch cycle survey, 1989

Serious injuries in selected movement codes

	Chch survey (Cambridge et al) % of contributing factors†		This study: Expected crashes with contributing factor	This study: Actual crashes with contributing factor	Codes
Specific cyclist faults	-	-	-	30	(40*)
Bad brakes	2.9	(17.2)	11	5	(933)
Other mechanical	6.2	(11.2)	23	1	(932-4-6)
Lost control	24.6	(34.8)	93	6	(43*)
Not seen in time	43.3	(22.2)	164	-	
Driver failed to give way	-	-	-	112	(12*/28*)
Driver inattentive etc	-	-	-	89	(22* to 25*)
Driver too fast	-	-	-	8	(11*)
(Driver codes subtotal)				(209)	
Crowded by vehicle	9.5	(10.1)	36	-	
AC + AF + GB, cycle 2nd vehicle	-	-	-	28	
In rain, poor visibility or strong wind	-	-	-	50	(M, L, H, S)
On wet or icy road	-	-	-	56	(W, I)
Road wet and slippery	7.4	(7.7)	28	-	
Rain	6.0	(9.3)	23	-	
Ice or frost	4.0	(5.7)	15	-	
Road surface poor	-	-	-	0	(81*)
Loose gravel	11.0	(25.6)	42	-	
Road rough or bumps	5.9	(14.8)	22	-	
Totals	**140**	**(172)**	**531**	**379**	

† Percentages for children are given in brackets. Some information in Cambridge et al (1991) is omitted.

Recommendation:

- Investigate improved recording of the factors in Table 4.3 to assist cycle facility designers. These include: Did not stop at traffic signals, Swerved..., Wrong way in one-way street, Wandering or wobbling, Not using cycleway, Riding on footpath and Road slippery, uneven or narrow (14).

4.20 Data quality

There are problems with the quality of cycle crash reporting. This is international: McClintock (1992, p 81) refers to a German term for missing data on cycle crashes, *dunkelziffer* (dark figures), and quotes studies showing that up to 60% of serious injury crashes may be missed. This is about the New Zealand figure, suggesting that our data is towards the poor end of the international range.

Cycle crashes are more difficult to investigate than motor vehicle crashes and there is no specialist training in this country.

> *Physical evidence left by cyclists or pedestrians is delicate and short term in nature. If not collected within minutes of a crash it may be irretrievably damaged by passing traffic.*
> (Brown 1996, page 15)

> *It is not unknown for drivers to claim that they were stationary when the collision occurred, particularly with a cyclist.* (Brown 1996, page 16)

Two other forms of inaccurate reporting are known to me personally.

- I was involved in a crash, as a cyclist, in 1994. It was reportable, reported and investigated (the driver complained that I had *dobbed her in*) but does not appear on the database. Anecdotal evidence is that reported crashes 'often' disappear in this way.
- A friend's son was killed in a crash at night (No 96/10042, movement code LB, cycle key vehicle), and forensic examination concluded that his cycle headlight had not been working. My friend thought this unlikely and was able to show that the only thing wrong with the light was bent contacts due to the force of the collision. The database records the corrected information.

The frequency of citing conspicuity as a contributory factor suggests poor recording. Overall, conspicuity was cited in 14% of fatal crashes studied but only 5% of serious injury crashes. This suggests that cyclists are being unfairly blamed if they are unable to give their version of events. I assume that conspicuity 'ought' to be cited in the same proportion of serious injury crashes as fatal crashes, which will be correct at the near-fatal end of the serious injury spectrum but may not be correct overall.

An alternative hypothesis is that over-citing has been a problem but has been or is being overcome, and the figures above reflect the longer period chosen for fatal crashes. Taking the fatal crashes for 1994–96 only (the same period as for serious injury crashes), conspicuity was cited in 10% of fatal crashes, twice as often as serious injuries, but numbers are too small to be sure that citing rates have changed.

The OECD (1986) state that, *one decisive accident cause is almost never to be found. Accidents can instead be regarded as the sum of several simultaneous random factors.* However, of the crashes selected for detailed study (excluding head-ons), 34% of fatal and 43% of serious injury crashes have only one 'probably contributing factor' cited. Again, this suggests poor-quality reporting.

Recommendations

- Investigate methods of improving the accuracy of information gathering (10).
- Provide police training in advanced crash investigation (as recommended in Brown, 1996) (15).
- Investigate the high rate of citing conspicuity as a factor in cycle crashes (67).

4.21 Bias

The LTSA database has several biases in its presentation of cycle crash data, in addition to the problems discussed in 4.20.

Problems and possible problem indicators include the following.

- Cycle crashes are not usually recorded unless a motor vehicle is involved: see 2.3.
- The driver's proportion of cited contributory factors is 42% overall, which is out of step with overseas studies. These include 80% and 83% driver factors in studies in the UK (Ballantine, 1976 and Cyclists's Public Affairs Group, 1996) with 95% motor vehicle involvement (British Medical Association, 1992) and 66% in Erlangen, Germany, with motor vehicle speeding the most frequent cause (Bracher, 1992). Hass-Klau (1991) concluded that 25% of all crashes in Germany could have been *avoided* if drivers had observed speed limits.
- Few cycle crash reports cite driver speed or alcohol as a contributory factor.
  - Driver alcohol: 18% of cycle fatal injuries but 36% of all crashes.

– Driver speeding: 6% of cycle fatal injuries but 37% of all crashes.

(Overall figures from LTSA, 1994, p 49) Cyclist alcohol is cited as a factor in 4% of fatal injury reports. These figures are conservative because all alcohol codes have been taken together, including 101: Alcohol suspected, and 102: Alcohol test below limit.

- Auditing of individual crash reports (Appendix C) shows several examples of bias, including:
  - The driver's speed in a 50 km/h area was *at least 75 km/h* according to a witness but speed was not cited. (FA: 87/2009)
  - The driver claimed to have been travelling at about 70 km/h in an 80 km/h area but stopped 120 m beyond the impact point. The road was dry so even with no advance warning the stopping distance at 70 km/h should have been about 40 m (HMSO, 1996). No faults were cited. (FA: 90/00335).

These points are not provable but should be clear enough for inclusion in 'probably contributing factors' in the database.

Bias is also built in to the reporting form, with cyclists and pedestrians treated separately from motor vehicles and in much less detail. A revised form is needed, treating drivers, pedestrians and cyclists equally.

Recommendations

- Investigate methods of minimising bias in the LTSA database (11).
- Revise the form used for crash investigation (TAR 565) to treat drivers, cyclists and pedestrians in the same way (16).

4.22 Changes in cyclist's risk

The database shows declining numbers of cyclists killed and injured but this does not necessarily mean safer cycling. Other explanations include improved medical response, such as rescue helicopters, and declining cycle use. No estimate of risk is possible from the database alone. The only proper exposure data located for New Zealand is in MoT (1992). Atkinson and Hurst (1984) give an overall cyclist's risk figure of 240 fatalities per billion kilometres but this is doubtful. It is extremely high—four times the current rate—and is derived by extrapolating from injury to fatal crashes.

Cambridge et al (1991, figures 2 & 5) show cycle injury crashes in Christchurch increasing by 29% in the decade to 1989, with morning peak hour cycle use declining over the same period by 60% for students and 70% for adults. This suggests that cyclist's risk almost doubled, but numbers are derived from limited screen line counts and may not indicate exposure reliably. Bachels (1996, p 6) refers to declining cycle safety in Christchurch over the past few decades.

Kingston Morrison (1997, p 3.17) say, in a report to Wellington Regional Council:

> *The presently poor availability of safe routes for cyclists is slowly getting worse. Each new road scheme that is built without some consideration of the needs of cyclists is progressively squeezing cycle users off the roads. This process will continue until the requirements of cyclists* (are) *integrated into the routine road planning and design methodology.*

A check of 9 road junctions improved on safety grounds shows that 6 have been made more dangerous for cyclists, three of them substantially so. See Table 3.11.

A car overtaking a cycle has become a more dangerous manoeuvre since 1980–87: see 4.5.

Commuter cycling (the only cycling recorded nationally: see 4.2) declined by 17% between 1991 and 1996. Over this period the number of cycling deaths and injuries also declined at much the same rate, but with too much year-by-year variation for firm conclusions to be drawn.

I conclude that cyclist's risk probably increased in Christchurch from 1979 to 1989, and may have increased nationally. Some road improvements made on safety grounds seriously affect cyclist safety or mobility. The current decline in cyclist deaths and injuries is probably due to falling numbers (Table 3.1) and may conceal increasing risk.

Recommendations

- Fully integrate cycle provision into road planning and design methodologies (24).
- Check the change in cyclist's risk between the 1989–90 and 1997 Household Travel Surveys when the latter is published (68).

5 General crash reduction measures

5.1 Introduction

This section looks at general—as opposed to site-specific—methods of crash reduction.

5.2 Motor vehicle speeds

Motor vehicle speed is crucial in determining the frequency and severity of cycling accidents (Shayler et al, 1993, McClintock, 1992). O'Flaherty (1997) says that higher speeds make gap acceptance more difficult for elderly pedestrians. Young cyclists may also be at risk here. Hass-Klau et al (1990, p 2) give the likelihood of fatal injuries as 5% at 30 km/h, 37% at 50 km/h, and 83% at 70 km/h. These figures and their limiting conditions suggest an S-curve. A plot on cumulative probability paper puts the points on a reasonably straight line, again suggesting an S-curve, and also suggests 1% and 99% probabilities at 8 and 102 km/h. See Figure 5.1[6] .

The main curve in Figure 5.1 shows the risk of death to a pedestrian or cyclist for a given closing speed and no warning. This is modified as shown by the broken lines if the danger is seen 10–30 m before impact—typical junction dimensions—and brakes applied. Assumptions are a reaction time of 0.7 s and a deceleration of 6.5 m/s^2 (both implied in a braking distance table in HMSO, 1996). At 50 km/h an available braking distance of 15 m makes very little difference—it is mostly used in reaction time. Twenty metres allows more braking distance, reducing the risk of death from 37 % to 15% (this is the difference in risk between the main curve and the 20 m curve at 50 km/h: the reduced impact speed can be read from the main curve for the reduced risk level).

In contrast, at 30 km/h and with 15 m available, a crash can be avoided.

It seems sensible that—if the safety of all road users is important—urban speed limits should be set so that slight speeding does not take a driver too far up the steep section of the fatality risk curve for pedestrians and cyclists. It follows that a speed limit of 50 km/h is too high on most urban roads and 30 km/h is a good choice for most unsegregated urban roads. It is an increasingly common choice in Europe, and Carlo (1998) reports that the Netherlands government is considering introducing it on all but the most major urban roads. Even lower speed limits—15 or 20 km/h—are used in some residential areas, with priority for pedestrians and cyclists (Children's Play Council, 1998).

Plowden and Hillman (1996) studied reducing UK speed limits to increase safety, concluding that major speed reductions could save as much in lower crash costs, fuel use etc as they would cost in increased road user time. Preliminary recommendations, which they say are probably conservative, are given in Table 5.1. The original figures were rounded to 5 miles/h (8 km/h): I have added bracketed figures to suggest practical metric values.

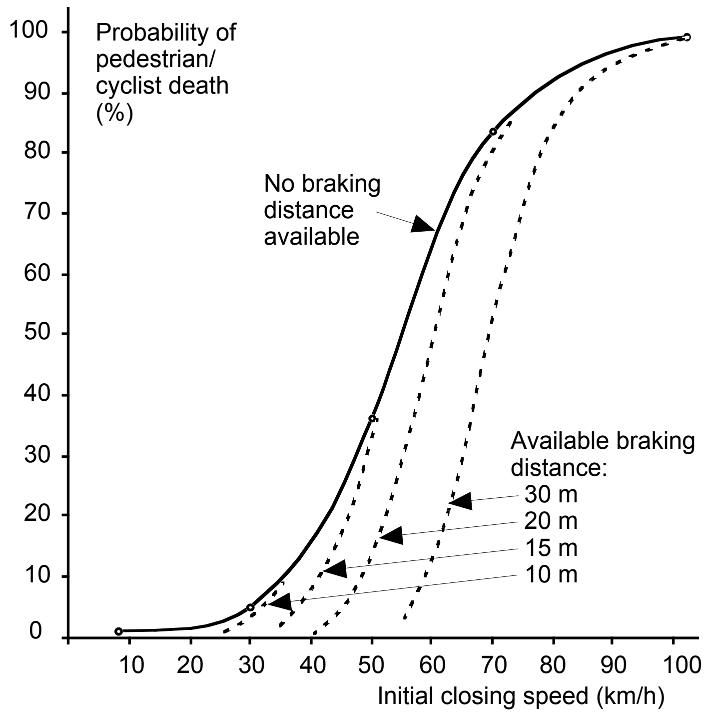


Figure 5.1: Impact speed and probability of pedestrian/cyclist death

For light vehicles on a dry road. See footnote(2008)

Table 5.1: Reduced speed limit recommendations for the UK

from Plowden and Hillman (1996)

Motorways	97 km/h	(100 km/h)
Other divided highways	89 km/h	(90 km/h)
Non-divided rural arterials	65 km/h	(70 km/h)
Urban arterial	(varies)	(50–60 km/h)
Other urban roads	32 km/h	(30 km/h)

6 (2008) Note that other information suggests that Figure 5.1 is optimistic and that the probability of death should be about 40% at 40 km/h, 70% at 50 km/h and 90% at 60 km/h (Patterson, T, Frith, W and Small, M (2000). *Down with Speed.* Wellington: ACC and LTSA)

If the figures in Table 5.1 are optimal for the UK it seems reasonable to assume that optimal figures for New Zealand would be similar.

Recommendations:

- Use speed limit enforcement margins that are as low as practicable (17).
- Consider 20[7] km/h speed limits for use in selected residential streets, with priority for cyclists and pedestrians (26).
- Investigate applying benefit/cost analysis to speed limits (69).

5.3 Social attitudes to speed

Anecdotal evidence suggests that in New Zealand social attitudes towards vehicle speeding are particularly bad, with poor driver behaviour towards cyclists and pedestrians. See Section 11.

5.4 Route Planning

Throughout this study there is tension between providing for cycling on roads used by other traffic and providing separate routes. On urban roads no general resolution is possible and the dilemma has to be resolved for each street, each block and even each part-block. Tensions may remain after a decision has been taken. CROW (1993, p 97–100) describe an iterative design process involving planners as well as engineers. If the intended street use cannot be realised in a design that is safe for all users the intended use is revised and the process restarted.

It is possible to place too much emphasis on route planning (Newman, 1996) but obviously some planning is needed. However, in the initial stages the network is a secondary consideration and the first priority is to solve existing problems—and avoid creating new ones. The World Bank (1996) draws attention to the need for safety auditing, to avoid expensive remedial work.

Important points in developing a plan are given below.

- The aim is safe cycling on an acceptably direct route between any two destinations, with all destinations accessible to most cyclists.
- A full understanding of existing routes (McClintock, 1992), including those routes avoided and those routes used unofficially or even illegally.
- Consultation with cycling groups and major cycle traffic generators (schools, employers etc).
- Recorded cycle crashes may give a very misleading picture (McClintock, 1992). A junction where there are few crashes may be safe or may be avoided because it is dangerous.
- Off-road cycle routes need provision for maintenance.
- Keep the *five main requirements* (see 1.5) in mind.

5.5 Safe routes to school

Safe cycling routes to school will be one of the most important initial phases of a safe cycling programme. Measures such as this are given a high priority in Christchurch[8]. Children need a particularly high standard of safety, although a comparatively slow route is acceptable. For example, children could be expected to dismount to cross a busy street. Points for safe cycling to school are given below.

- Avoid roundabouts. See 3.8.
- Separate children from heavy and fast moving traffic.
- Avoid situations where children have to turn right without protection: specifically movement codes JA (crossing vehicle turning right), AA (pulling our or changing lane to right), GC (stopped or turning from left side) and LB (right turn against). Movement code HA (crossing, no turns) also needs care.
- Children are easily confused by traffic coming from more than one direction. See 11.3. Leden (1993) suggests that, for pedestrians, a mid-block crossing may be better than crossing at a junction. The same advice could be useful for young cyclists, even if they had to wheel their cycles on the footpath for some distance.

Table 5.2 gives preferred and maximum traffic levels for various situations, adapted from Leden (1993). While originally developed for pedestrians, these figures also seem relevant for young children on cycles, who in practice are often pedestrians on wheels and should perhaps be treated as such: see 10.2.

Recommendation

- Safe cycle routes to school should avoid situations where children have to turn right without either special protection or a 30 km/h zone. Movement codes JA, AA, GC, HA, and LB need special care (34).

7 (2008) This figure looks very much like a typo: it should be 30 km/h. See 5.2, 6.2 and Appendix E.

8 Alix Newman, Christchurch City Council Projects Officer, personal communication

Table 5.2: Preferred and maximum traffic levels for safe routes to school

Adapted from Leden (1993)

	Speed 30 km/h		Speed 50 km/h	
	Preferred (Veh/h)	Maximum (Veh/h)	Preferred (Veh/h)	Maximum (Veh/h)
Pedestrian crossing at junction	<100	<300	–	<300
Street with parked vehicles	–	<100	–	–
Pedestrian crossing with central refuge	<300	<500	<300	<500
Pedestrian crossing with separate phase	<300	<500	<300	<500
Pedestrian/cycle route beside busy road, vehicles on intersecting street	<100	<300	<100	<300

5.6 Savings due to cycle-friendly design

Traffic calming is usually justifiable using conventional benefit/cost analysis: Hass-Klau et al (1992) quotes benefit/cost ratios from 1.1 to 39, and Rose (1995) quotes a first year rate of return of 338%. These savings are due to very large reductions in casualties, with quoted average reductions of 60% overall (The Association of Metropolitan Authorities et al, 1996), 67% overall (Clare, 1996), 67% for child pedestrians and cyclists (Royal Commission on Environmental Pollution, 1997, box 4a) and even 75% for child pedestrians and cyclists (Huxford, 1997). However, the only estimate seen which gives a confidence range is in Roberts (1994), who gives a 78 % reduction in serious injuries and a 95% confidence interval of 26 –93%.

A 60% reduction in casualties seems a reasonable assumption for the UK: see 8.4 for comments on transferring this figure to New Zealand.

5.7 Potential cycle traffic

The potential for increasing cycle use depends very much on the facilities provided. Publicity, attitudes, and the perceived cost of motor vehicles are other considerations. A close-grained network of continuous and good quality routes is needed for success. Nothing is achieved by painting cycle lanes where there is already plenty of space and ignoring more difficult locations. Indeed, poor facilities may make a bad situation worse (McClintock, 1992, p 36), by increasing driver's expectations that cyclists will keep out of their way, increasing cyclists' safety expectations, discouraging cyclists from riding in a safe position on the road (Franklin, 1997) and increasing conflicts with parked cars.

The following assumptions seem plausible for initial estimates. See 8.5 for comments on transferring this overseas data to New Zealand.

- The cycling growth rate proposed by the UK's National Cycling Strategy is attainable in New Zealand. This is a doubling in 6 years then another doubling in 10 years (Royal Commission on Environmental Pollution, 1997).
- Distance is relatively unimportant to commuters on a segregated route that is as quick as alternative modes. This is suggested by stated preference research in the UK (Wardman et al, 1997), which predicts that under good cycling conditions some 12–14% of car commuters will transfer to cycling.
- New Zealand's low urban densities will increase trip lengths and so tend to reduce cycle numbers, but better weather will tend to offset this.
- Some UK employers have already achieved up to 25% of employees commuting on cycles (Update, 1998).
- UK data reported by Shayler et al (1993) indicates that with safe cycling the ultimate potential for cycling is nearly 26% of work trips overall and up to 49% in cities with flat terrain.
- Ultimate cycling levels in New Zealand could approach the levels achieved in some European cities: over 50% of commuters in Groningen, and over 30% in Munster, Delft and Copenhagen, but subject to the limitations of hills and comparatively low urban densities.

Recommendation:

- Set a target of a doubling of cycle numbers within 6 years, then a further doubling within 10 years, to reach a national figure of 16% of commuters on cycles by 2016 (2).

5.8 Cycle theft

Welleman (1997) points out that cycle theft is a safety issue. If theft is commonplace the quality and maintenance of cycles will suffer as cyclists use old machines, and this is likely to be reflected in increased crashes where cycle condition is a factor. The most effective solutions are cycle lockers and supervised cycle storage, but supervision is impractical unless cycle numbers are very large or casual supervision can be arranged, such as workplace cycle parking within employee's view.

5.9 Cycle design

There is very little to be gained in further cycle design for safety. There are two fundamental problems.

- All work is done by the rider, so cycle weight slows acceleration and contributes directly to the effort of going uphill.
- A vehicle weighing as little as a cycle sustains very large acceleration in a crash with a motor vehicle weighing upwards of 700 kg. This alone could be fatal to the rider, even if she or he could be protected in other respects.

Fully and partially enclosed cycle designs exist but are intended more for streamlining and weather protection than to protect the rider in a crash. Some designs are simple fairings for conventional cycles and may be very exposed to crosswinds. Others are of radical design and are well streamlined: one manufacturer claims that most people can reach speeds of over 90 km/h (Clouston, 1995), but at 18 kg (some 30 times less than the lightest car) it cannot offer significant protection.

A recumbent position allows heavy braking without risk of being pitched over the front of the cycle, and in some crash types the rider hits feet-first instead of head-first. However, the low position makes riders less visible and more at risk when side-swiped. Two-wheeled recumbents are surprisingly unstable because of comparatively long wheelbase, low moment of inertia in roll and high moment of inertia in yaw. When ridden they cannot be lifted over a kerb or pothole by jerking the handlebars.

An ordinary ('penny farthing') bicycle offers theoretical safety advantages in a serious crash. Visibility is excellent, and with the saddle up to 2 m above the road a collision with a car would be below the rider's vital organs. However, brakes are inevitably poor because of the danger of going over the handlebars and falls are often serious. There were good reasons for calling the machines that replaced the ordinaries 'safety bicycles'.

5.10 Motor vehicle design

The Institution of Civil Engineers (1996) mentions pedestrian air bags on motor vehicles as a possibility. This would also help cyclists, but New Zealand has very little influence on the development of such devices. Three measures could be taken locally.

- Tougher regulations against bull bars. New regulations have just been introduced, but are not adequate for cyclists and especially child cyclists. A photograph of a bullbar passed—after some argument—shows square-edged members extending to a height of some 1.2 m (Maxwell, 1998).
- Restrictions on trailers wider than the towing vehicle.
- Side guards on trucks.

6 Physical measures between junctions

6.1 Introduction

This section considers the problems of cycle provision on roads. The problems of provision at road junctions are considered in Section 7.

6.2 Appropriate design

It is difficult to design a cycle facility for use by both family groups with young children, travelling at perhaps 8–12 km/h, and sports cyclists travelling at 40 km/h or more. Sports cyclists and the fitter commuter cyclists tend to avoid facilities designed for riders towards the slow and wobbly end of the speed and skill spectrum, as is happening in Oriental Bay, Wellington.

Austroads (1993, p 74) recommends design speeds of 30 km/h for recreational paths and 50 km/h for commuter routes.

6.3 Street space

Off-street cycle routes are sometimes available but street space usually has to be taken from motor vehicles if cyclists are to have adequate room (CROW, 1993, Fietsersbond, 1997). O'Flaherty (1997, p 467) points out that 30 km/h speed limits allow reduced motor traffic space without affecting capacity. Even reducing motor traffic capacity is likely to be acceptable once it is realised that traffic levels are much more flexible than is usually assumed (Standing Advisory Committee on Trunk Road Assessment, 1994, Tolley and Turton, 1995, Heierli, 1996, Cairns et al, 1998).

New Zealand cities tend to have wide streets, giving good opportunities for cycle provision. Lane narrowing may be seen as dangerous but is acceptable if speeds are reduced where needed. A risk compensation approach is helpful here: see Section 11.4. Sustrans (1997, p 39) will accept two cycle lanes and two traffic lanes in as little as 8.5 m between kerbs: 2 x 1.5 m cycle lanes and 2 x 2.75 m traffic lanes. See Figure 6.1: only the bottom layout is illegal in New Zealand.

Even narrower lanes may be acceptable if at least one 3.0 m lane each way is available for trucks, or trucks are allowed to straddle two lanes. CROW (1993, p 98) suggests widths (for cars) down to 2.25 m between kerbs, and refer specifically to using road narrowing to slow traffic (p 73). Tolley (1989) gives a variety of layouts with similar lane widths, from German practice. These include a two way

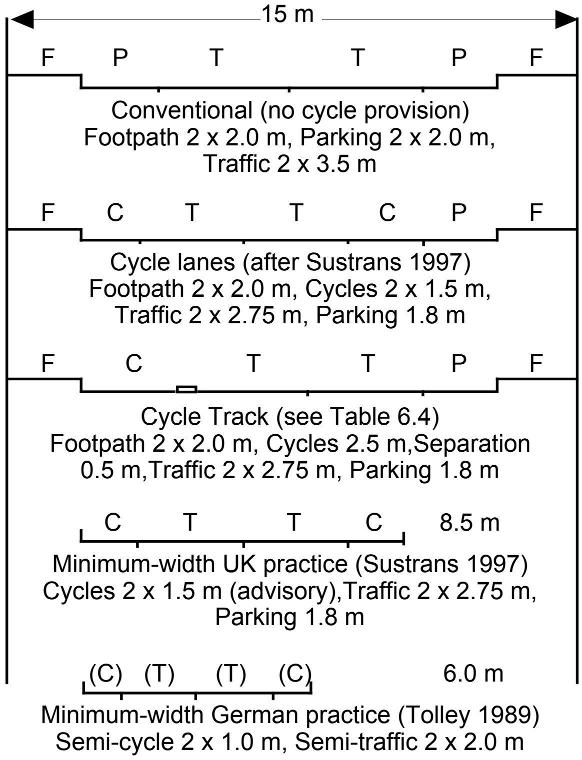


Figure 6.1: Options for fitting cycles into a 15 m street width

Markings above the road surface indicate kerbs, markings below indicate painted lines
C = Cycles, F = Footpath, P = Parking, T = Traffic

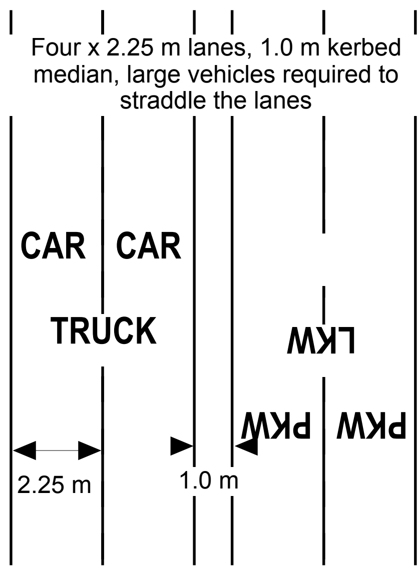


Figure 6.2: 'Almost a 4 lane highway'

Four lanes fitted into 10 m width.
Markings show the original German and a presumed translation.
Adapted from Topp (1990)

access road as narrow as 4.0 m, with 1.0 m safety strips either side as combined cycle lanes and overrun areas for trucks. In effect the road is 6.0 m between kerbs with 2 x 2.0 m semi-traffic lanes and 2 x 1.0 m semi-cycle lanes.

Topp (1990), again reporting German practice, describes a four-lane highway in a width of 10 m, specifically intended to make room for bus or cycle lanes. Lane widths are 2.25 m with a kerbed median 1.0 m wide. Trucks and any remaining buses are expected to straddle two lanes. Topp describes this as *almost a four lane* highway but recommends a maximum length of 800 m. See Figure 6.2.

Another source of street space is to eliminate flush medians. These are popular as a safety measure in New Zealand but rarer in Europe (Wood, 1997). This suggests that the safety effects may be due to using up excess road width rather than any inherent qualities, and that using the width for cycle lanes or tracks may bring similar benefits.

Recommendation:

- Investigate the safety effects of using road space for cycle facilities rather than as a flush median (71).

6.4 Effect on road and parking capacity

Wright (1991) gives relative capacities for cars and cycles, expressed as persons per hour per metre width. His figures are 200 persons/h.m width for cars and 1480 pers/h.m for cycles, or a ratio of 7.4 :1. Hudson et al (1982) give a tenfold difference. These figures seem high, so a conservative check is made in Appendix F, summarised in Table 6.1. The factors in Table 6.1 are capacity multipliers: see Appendix F for capacities in persons/hour. For example, converting a 3.0 m lane to a cycle track increases capacity from 2400 persons per hour in cars (assuming 1.44 persons per vehicle) to 8200 persons/h on cycles, an increase of 3.4 times. There is a substantial increase in all cases, of 60–460%.

Cycle parking is typically at a density some 7–8 times greater than car parking, again measured in people-carrying terms.

6.5 Speed and lateral clearance

Cyclists are sensitive to lateral forces because of their need to balance and this causes them difficulty with wind gusts. A particular problem is the pressure wave of air flow around a fast-moving motor vehicle. A large truck travelling at 100 km/h may displace air weighing three times as much as a cyclist, every second. The forces developed can affect a light car, and cycles need additional clearance for safety. Austroads (1993, Figure 3.1) gives the minimum clearance between the 'cycle design envelope' (taken as 1.0 m wide) and the edge of an adjacent traffic lane as 0.5 m at 60 km/h and 1.5 m at 100 km/h. It follows that for motor vehicle speeds of 100 km/h the minimum cycle lane width is 3.0 to 3.5 m, depending on left hand edge conditions. A lane as wide as this is ideal for motor vehicle parking, as a crawler lane or for acceleration and braking at junctions and private entrances. CROW (1993) states that this is what happens. CROW recommends a maximum width of 2.5 m and avoiding cycle lanes alongside high speed traffic.

At the opposite end of the scale, cyclists need additional clearance at low speeds because of their need to balance. CROW (1993, p 16) suggests an additional 0.3 m at 11–20 km/h and up to an additional 0.8 m below 10 km/h. This is contrary to the advice given in National Roads Board and Urban Transport Council (1985, Figure 4) that cycle lane widths can be reduced to 1.2 m at traffic signal approaches.

6.6 Cycle lanes

In New Zealand cycle lanes are seen as the normal method of providing for cycling but European best practice is to limit their use to a narrow range of

Table 6.1: Capacity increase with dedication of road space to cycle use

Available width (m)	New use		Capacity increase multiplier
3.0	Conversion to cycle track		3.4
3.5	Conversion to cycle track		4.1
4.0	Conversion to cycle track		4.6
4.5	1.5 m cycle lane, 3.0 m traffic lane		2.0
5.0	1.5 m cycle lane, 3.5 m traffic lane		2.2
	2.0 m cycle lane, 3.0 m traffic lane		2.7
5.5	2.0 m cycle track, 0.5 m separation, 3.0 m traffic lane		2.7
	2.5 m cycle track, 3.0 m traffic lane		3.3
7.0	2 x 3.5 m traffic lanes before conversion		
	1.5 m cycle lane, 3.0 + 2.5 m traffic lanes	etc	1.6

traffic speeds and volumes. CROW (1993) give guidance on acceptable combinations of motor vehicle speed and volume for mixing with cycles, recommending a maximum speed of 30 km/h for 1000 vehicles/h, rising to 50 km/h for 550 vehicles/h and an absolute maximum motor vehicle speed of 60 km/h with negligible vehicle numbers. Sustrans (1997, p 15) modify the CROW curves to *...reflect the needs of the inexperienced cyclist or family group who will benefit from segregation earlier than the experienced cyclist.*

Figure 6.3 gives Sustrans recommendations. It can be seen that acceptable traffic volumes for mixed road use fall rapidly at speeds above 30 km/h. Clearly, lower speed limits and better control of motor vehicle speeds are needed if cyclists are to have maximum access to the roading system.

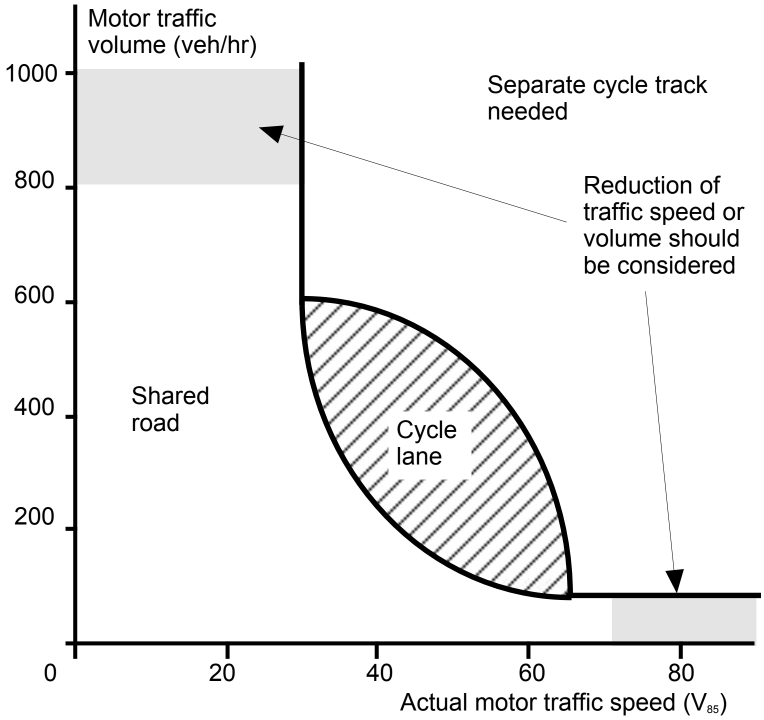


Figure 6.3: Traffic speed/volume criteria for cycle lanes

Adapted from Sustrans 1997

Godefrooij (1997, p 235) points out that cycle numbers are not a consideration: if a given layout is unsafe for large numbers of cyclists it will also be unsafe for a few (or even less safe: see Figure 4.1). This is in contradiction to the advice in National Roads Board and Urban Transport Council (1985, Figure 5.1), which relates facility needs to cycle traffic flows. However, Godefrooij says that the number of cyclists does matter in prioritising construction of cycle facilities.

Godefrooij (1997) suggests that the following considerations be used with the CROW capacity/flow diagram:

- *When there is much parking, bicycle lanes are not advisable. These lanes will be abused as parking space.*
- *A bicycle track or lane can contribute to the coherency and recognisability of a bicycle route. If a road section is an important link in the bicycle network, this could be an argument in favour of the segregated facility.*
- *When there are many (large) intersections, bicycle tracks will lose their value. The comfort of untroubled cycling will be affected negatively by the necessity of being careful at intersections (when only minor streets are entering the road this is less of a problem).*
- *In cases of one-way streets with permitted cycling in the opposite direction, segregation (contra-flow lanes or tracks) is more desirable than in other situations.*

Godefrooij says that cycle tracks are more common than cycle lanes in the Netherlands, which is in contrast to New Zealand practice.

The Austroads concept of a combined cycle and parking lane is not used in the CROW and Sustrans manuals. Where parking is allowed on the kerb side of a cycle lane it is in marked bays, usually with a marked safety strip between parking and cycles. European practice seems better than Australian practice here, as it makes the cycle lane more visible to drivers using the parking bays. This should reduce the risk of crashes of movement code type A (changing lane) and EA (hit parked vehicle: includes door opened into cyclist's path).

Cycle lane widths suggested by the three source documents considered are given in Table 6.2, together with suggested figures for New Zealand.

Recommendations:

- Limit new cycle lanes to situations within the safe traffic speed/volume limits of Figure 6.2, and phase out existing non-complying lanes (45).
- Cycle lane widths should be 1.8 m preferred, 1.5 m minimum and 2.5 m maximum. These figures may include the width of the lane line but must not include uneven surfaces unsuitable for cycling. Additional width is needed close to fixed objects or where cyclists have to slow or stop (46).
- Cycle lanes are inappropriate where there is high parking turnover (47).

Table 6.2: Recommended cycle lane widths

Data from CROW (1993), Sustrans (1997) and Austroads (1993)
Note that the table includes some interpretation of information presented in different ways.

	CROW (m)	Sustrans (m)	Austroads (m)	Suggested NZ (m)
Cycle lane - minimum	1.5†	1.5	1.0	1.5
Cycle lane - desirable	–	–	1.5 Δ	1.8
Cycle lane - maximum	2.5	2.0	–	2.5
Bus/cycle lane	4.2–6.2*	4.25–4.6	–	4.2
Wide nearside lane	4.3–5.0	–	3.7–4.5 Δ	4.2
Separation from parallel parking				
- minimum	0.0	0.5	–	0.3
- preferred	0.75	1.0	–	1.0
Separation from angle parking	1.0–1.5	–	–	1.0–1.5
Combined cycle/parking - minimum	–	–	3.5	–
Combined cycle/parking - preferred	–	–	4.2 Δ	–
Preferred additional width where cycles stop frequently	0.8	–	–	0.8

Note: Additional clearance is needed where street furniture is within 0.5 m of the cycle lane, or within 0.75 m where a fence or wall is parallel to the cycle lane (CROW, 1993, p 84).

* For cycle traffic in both directions

† Ministry of Transport (1994, p 86) report studies in the Netherlands showing that half of Dutch cycle facilities are too narrow, and recommend a minimum of 1.8 m, including a 300 mm separation line. Bicycle Victoria usually use 1.8 m lanes (Cumming and Shepherd, 1996).

Δ At 60 km/h

- Do not use combined parking-cycle lanes, but mark parking bays and a cycle lane separately, with a safety strip (48).

6.7 Critical profile

A useful concept in CROW (1993) is critical profile, or critical width. The principle is that where cycles and motor traffic are mixed there should always be either enough width for safe overtaking of cycles (spacious profile), or insufficient width for drivers to try overtaking (tight profile, maximum speed 30 km/h). In the latter case the section length should not be more than 300 m (about 1 minute at 20 km/h). The details are fairly complex (10 pages in CROW) and are briefly summarised below. See Table 6.3.

The upper part of Table 6.3 shows assumed vehicle widths and clearances and the lower part some examples. Note that the road width between kerbs has to be considered as a kerbed median affects behaviour. The two narrow profiles shown are for a car and a truck, but the truck profile cannot be used in practice because it is a critical width for a cycle-car combination: wider than tight profile (a) but narrower than spacious profile (c). In this case a compromise width of 2.6 m is recommended unless truck traffic is very heavy. All combinations need to be checked for such clashes and less common combinations frequently have to be ignored.

Where no special cycle facilities are provided the Department of the Environment, Transport and the Regions (1997) recommend a minimum lane width of 4.25 m where trucks may overtake cycles, but also say that this width should not be exceeded at traffic signals, as light vehicles may form two lanes. This is very similar to spacious profile (c) in Table 6.3. Presumably profile (d) is not required because it is assumed that another lane is available to the right (for traffic in the same or opposite direction), and trucks can partially use that lane. However, extra width may be needed at traffic islands: see 6.10.

Recommendation

- Kerb side traffic lanes in a 50 km/h zone should be 4.2 m minimum width. In a 30 km/h zone the minimum width should generally be 3.85 m but a *maximum* width of 2.6 m may be used over short distances (52).

Table 6.3: Component widths for calculating critical profiles, and examples

All dimensions in metres: data from CROW (1993)

Vehicle widths and clearances			30 km/h	50 km/h
Cycle	0.75	Cycle-kerb	0.25	0.25
Car	1.75	Cycle-parked vehicle	0.5	0.5
Truck	2.6	Cycle-moving vehicle	0.85	1.05
		Vehicle-vehicle	0.3	0.8
		Vehicle-kerb	0.25	0.5

	Intended use	30 km/h	50 km/h	Profile
a)	Car	2.25	–	Tight profile
b)	Truck	3.1	–	Tight profile*
c)	Cycle - car	3.85	4.3	Spacious profile
d)	Cycle - truck	4.7	5.15	Spacious profile
d)	Cycle - car - car- cycle	7.5	8.4	Spacious profile
e)	Cycle - truck - truck - cycle	9.2	10.1	Spacious profile

* Should not be used in practice: see text

6.8 Advisory and mandatory cycle lanes

Sustrans (1997) draws a distinction between advisory and a mandatory cycle lanes, recognised in UK law (Wheeler et al, 1993). CROW (1993) use a similar system but with a third category which seems unhelpful. Sustrans (1997) give two lane types.

Advisory lane:

May be used by motor vehicles when necessary, either to cross the cycle lane for parking or to access a side turning, or when there is insufficient width in the traffic lanes. Cycles in the lane have priority in all cases but are not required to keep to the lane.

Mandatory lane:

May be used by motor vehicles only in emergency or for private residential access, again with cycle priority but without compulsion on the cyclist.

Sustrans (1997) suggest the following uses of advisory and mandatory lanes.

- Advisory lanes are used at junctions, where there is kerbside parking or loading and at major accesses.
- Mandatory lanes are used wherever there is no need for an advisory lane. A mandatory lane crossing a private house entrance is acceptable.
- Short lengths of mandatory or advisory lane are acceptable.
- Where space is limited an advisory lane 1.5 m wide and a narrow traffic lane is better than a narrower mandatory lane: some encroachment by large vehicles can be accepted. However, this may not be acceptable if there is heavy truck traffic: see 6.6 and Table 6.3.

Sustrans (1997) show an advisory lane as having a broken line (estimated dimensions stripe 2.0 m, gap 1.0 m), and a mandatory cycle lane as having a solid line.

A problem in New Zealand is confusion between edge lines and cycle lane lines, although the difference should be clear enough. Drivers may expect cyclists to keep to the left of edge lines (Hynson, 1997). A further problem is that diagonal white stripes are recommended for cycle lanes wider than 1.8 m, or where there is motor vehicle parking on the kerb side of the cycle lane (Transit NZ, 1994, figure 2.11). Diagonal lines are also used in situations where stopping is permitted, and so invite drivers to stop on cycle lanes.

Two types of cycle lane line are used in Denmark (Ministry of Transport, 1994): a solid line 300 mm wide for use mid-block (although some photographs show narrower lines) and a line with very short stripe and gap (see Figure 6.4) used on junction approaches. Photographs suggest 300 mm width but with the stripe and gap as little as 30 mm.

Cycle lanes need a completely distinctive marking system. Two suggestions from European practice are to use lines where the stripe is the same as the width, or shorter (CROW, 1993, Ministry of Transport, 1993b), or to use a blue line[9]. A suggested approach using all white lines is shown in Figure 6.4.

A possible addition to the recommendations in Figure 6.4 would be to use a shorter stripe and gap (say half the standard values) where needed to attract cyclist's attention, such as the approach to a junction or pedestrian crossing.

9 Thanks to Liz Mikkelsen of Cycle Aware for this suggestion, which is used in Denmark

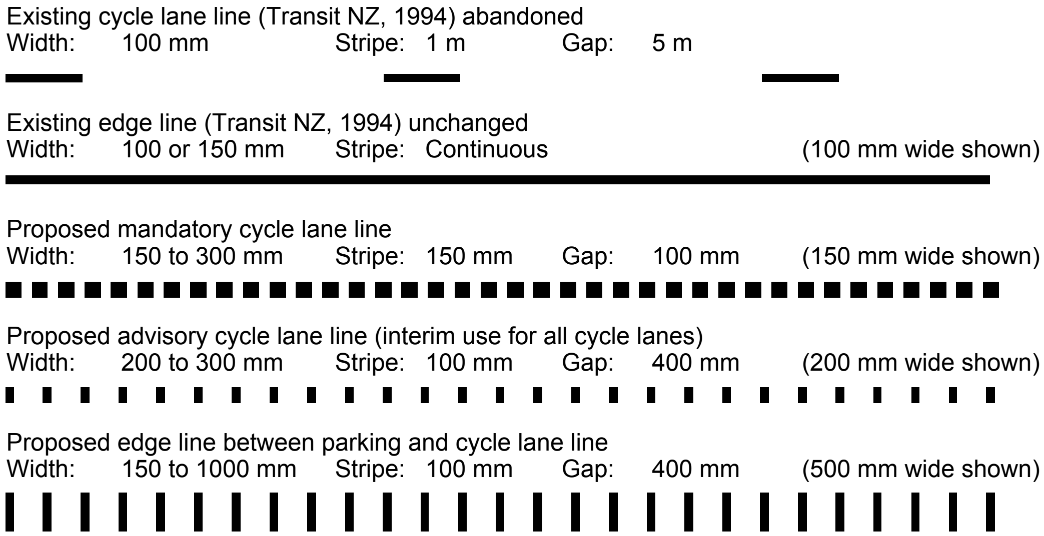


Figure 6.4: Existing and proposed lane markings

All markings white, supplemented where necessary by a red surface on the cycle lane

Recommendation:

- Develop cycle lane markings which cannot be confused with edge lines, sealed shoulders and flush medians, and publicise the new system. A suggested system is shown in Figure 6.4 (37).

recommend 0.5 –1.0 m. In either case the separation can be included in the 'between fences etc' width given in Table 6.4. However, Austroads (1998) does not permit a cycle track on the footpath side of parking.

6.9 Cycle tracks

A cycle track may be on a road alignment or take an entirely different route, and may cater for one or both directions. On-road options include the following.

a) On the traffic side of the kerb line, separated from motor traffic by a false kerb (with short gaps to maintain the original drainage). See Figure 6.5.

b) On the footpath side of the kerb line, separated from pedestrians by a painted line, kerb or false kerb. Jacobsen and Siboni (1992) suggest a kerb height of 30 mm and CROW (1993) recommend a maximum of 50 mm.

c) Cycle traffic in the opposite direction may be on the same track, on an equivalent track on the opposite side of the road or in a parallel street.

A safety strip is needed on the traffic side of the cycle track. This is especially important if parking is allowed, because vehicle passengers and pedestrians will not expect to find cyclists on the footpath side of parked vehicles. Car doors being opened into a cyclist's path are a particular problem. Figure 6.5 (a) shows two options for providing clearance when cycles are on the traffic side of the kerb, and Figure 6.5 (b) shows options for the footpath side. CROW (1993, p 88) recommend a safety strip 1.0 m wide, with a minimum of 0.8 m. Sustrans (1997, p 47)

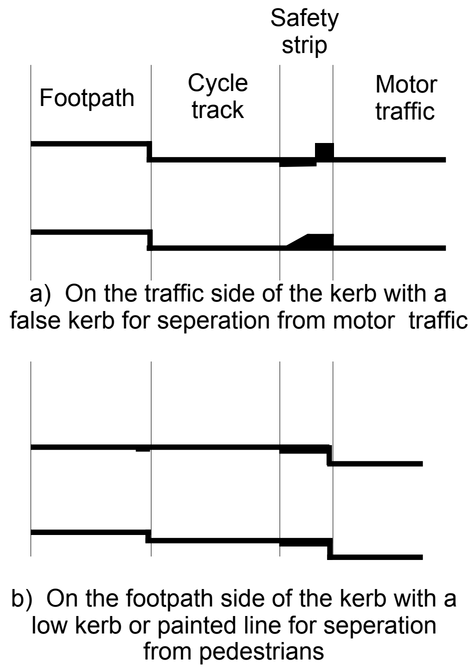


Figure 6.5: Cycle track cross-sections alongside a road

Two approaches to a cycle tracks at road and footpath level
Various sources, not to scale, painted surfaces shown as below surface level

Note that any of these arrangements may create problems if parking is allowed. Parked vehicles may hide cyclists from turning traffic at junctions and private entrances, and driveway crashes are the result. Bracher (1992) reports turning vehicle crashes tripling when the cycle track is on the footpath. See 7.4. One solution is to eliminate the parking, either close to junctions and driveways or throughout. If necessary illegal parking on the cycle track or dividing strip can be prevented by using bollards or a high kerb. Another helpful measure is to slow traffic using a driveway, using the kerb crossing effectively as a speed hump, if necessary with another hump at the false kerb.

Contra-flow cycling on a two-way cycle track may also create problems. Räsänen and Summala (1998) studied cycle-motor vehicle crashes where a cycle track crosses the leg of a T junction. They found that 64 % of cycle-motor vehicle crashes were movement code HA with the cycle as second vehicle. However, contra-flow cycling may be safer than the alternatives (McClintock, 1992, p 80), especially if a major junction can be avoided, and remains a useful option.

One- and two-way cycle track widths suggested by the three sources considered are given in Table 6.4 (next page).

Where a cycle track is alongside a road at a bus stop, the Danish Ministry of Transport (1994, p 66) recommend visually narrowing to 1.3 m using painted bars (to get the cyclist's attention), followed by a pedestrian crossing opposite each bus door at the stop. See Figure 6.6.

Cycle tracks need regular maintenance, especially sweeping of tracks alongside a road: motor traffic tends to drop small objects and the tyres sweep them onto the cycle track.

Recommendations

- Cycle track widths should be: seal 1.5 m minimum, clearance 2.5 m minimum. Greater widths are needed unless cycle numbers are very low (49).
- Cycle track designs should prevent motor vehicle parking close to junctions, entrances or the track edge (50).
- Two-way or contra-flow cycle tracks alongside a road need special care at junctions (51).
- Design cycle tracks for easy maintenance (64).
- Maintain cycle tracks regularly (65).

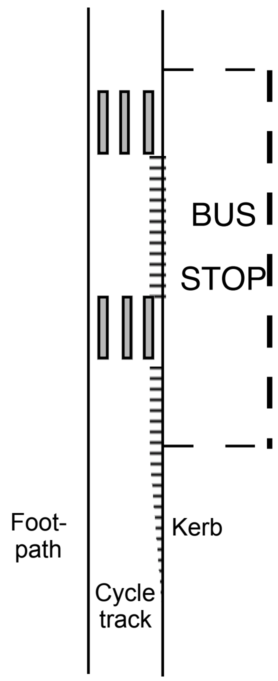


Figure 6.6: Cycle track at a bus stop

With mini-pedestrian crossings for bus boarding. Adapted from Ministry of Transport, Denmark (1994)

6.10 Bus-cycle lanes

All three of the overseas standards considered allow combined cycleways and bus lanes. CROW allows cycles to use a one-way bus lane in either or both directions but Sustrans say that bus lanes are *not ideal for young or inexperienced cyclists.*

Sustrans recommend a 4.25 m lane width and permit a 1.2 m cycle lane (narrower than standard) marked within the bus lane. The CROW manual covers both one-way and two-way lanes and tight and spacious profiles (see 6.7) for with-flow cycle use. Suggested spacious profile widths are 4.2 m for cycling in one direction and 6.2 m for both directions but with greater width on bends (p 112).

Table 6.3 suggests that a bus-cycle lane should be 5.15 m wide in a 50 km/h area (based on CROW data, assuming the same width as a truck-cycle lane), compared with about 4.2 m in Table 6.2. A plausible interpretation is that a bus-cycle lane should be 5.15 m wide if it is separated from other traffic by kerbs, but 4.2 m is sufficient for a painted separation only, as shown in The Bicycle Association et al (1996, p 42).

Table 6.4: Recommended cycle track widths

Note that the table includes some interpretation of information presented in different ways in the three source documents.

		CROW (m)	Sustrans (m)	Austroads 14 (m)	Suggested NZ (m)
One way					
Absolute minimum	- seal	1.5	-	-	1.5
	- fences etc	2.5	-	-	2.5
150 - 750 cyclists/h	- seal	2.5	-	-	2.5
	- fences etc	3.5	-	-	3.5
>750 cyclists/h	- seal	3.5	-	-	3.5
	- fences etc	3.5	-	-	3.5
Two way					
Absolute minimum	- seal	1.5	1.5	2.0	1.5
	- fences etc	2.5	varies	2.4	2.5
Desirable minimum	- seal	-	2.0	2.5	2.0
	- fences etc	3.5	3.5	3.5	3.5
Desirable commuter	- seal	-	3.0	3.0	-
	- fences etc	-	-	4.0	-
50 - 150 cyclists/h	- seal	2.5	-	-	2.5
(2 way)	- fences etc	3.5	-	-	3.5
>150 cyclists/h	- seal	3.5	-	-	3.5
...(2 way)	- fences etc	3.5	-	-	3.5
Two way—shared with pedestrians					
Absolute minimum	- seal	1.5	2.0	2.0	2.0
	- fences etc	2.5	3.0	2.4	2.5
Desirable minimum	- seal	2.5	3.0	2.5	3.0
	- fences etc	3.5	4.0	3.5	4.0
Desirable commuter	- seal	-	5.0	5.0	5.0
	- fences etc	-	-	6.0	6.0

Austroads (1998) shows a recreational path as needing a greater width than a commuter path: good sense if the pedestrian and cyclist peaks are together and bi-directional.

Recommendation

- Allow combined cycle-bus lanes, for cycle use in the same direction as buses or in both directions where appropriate. Recommended minimum widths are 4.2 m for cycles in one direction or 6.2 m for cycles in both directions. Where a bus route is on a separate road a minimum width of 5.15 m is need for sharing with cycles. Greater widths are needed on bends (56).

6.11 Pinch points

Pinch points are dangerous because they require a cyclist to move out into motor traffic, risking a crash of types AA or FA. Cyclists need protection, the traffic slowed or the pinch point eliminated. Some problems and possible methods are given below:

Bus stop

CROW (1993) show designs for running a cycle track to the left of a bus stop, to avoid bus-cycle conflicts. See Figure 6.6 for another approach. Austroads (1993) suggest a 1.5 m cycle lane on the traffic side of the bus lane.

Left hand bend

A solution given in CROW (1993) is a speed cushion just outside the cycle lane and just before the apex of the bend. A driver using the cycle lane to cut the corner cannot avoid going over the cushion.

Narrow bridge

Add a 'clip on' bridge, forming a short section of separate cycle track.
Care is needed to avoid forming another pinch point where the cycle route rejoins the road: see 6.14.

Narrow street

Use an alternative route, if a reasonably direct alternative is available, or reduce traffic lane widths to make room for a cycle lane or track, or use a 30 km/h speed limit.

The most common pinch point is a parked motor vehicle. The principle types of conflict and their possible solutions are given below.

- Using a cycle lane for parking, thus forcing cyclists out into the traffic lanes. Solutions are enforcement or using a cycle track.
- Parking too close to a junction, again creating a pinch point and also tending to hide cycles from drivers on the other legs of the junction. Solutions include enforcement or kerbs built out to prevent parking (care is needed to avoid creating another type of pinch point). Alternatively a kerb or bollards may be used to create a pinch point with a cycle by-pass.
- Opening a door into a cyclist's path. Cyclists and motorists can be educated about this risk but there is little that cyclists can do unless there is enough width for them to keep clear. Car parking should not be permitted where this is a significant risk.

Recommendation:

- Avoid or eliminate pinch points where cyclists could be trapped between an overtaking vehicle and a fixed object (57).

6.12 Traffic calming

Traffic calming schemes can be strongly supportive of cycling (McClintock, 1992, Sammer, 1993). The safety effects of a traffic calmed environment are discussed in 5.6. However, careless design of traffic calming features may be another source of pinch points affecting cyclists (Sustrans, 1997, Franklin, 1997). Features needing care are given below.

- Speed humps and speed cushions are best bypassed, especially where faster cyclists are expected: most cycles have no suspension. The hump ends are usually clear of the kerb, for drainage, but if this space is used as a cycle by-pass a gap of at least 1.0 m is suggested. CROW (1993, p 220–21) recommends a width of 1.5 m for a longer calming feature, Sustrans (1997, p 73) recommends 1.0 m minimum, and The Bicycle Association et al (1996, p 26) recommends 1.0 m with a minimum of 750 mm. Bollards or a raised island may be needed to prevent motor vehicles putting two wheels through the cycle bypass to increase passenger comfort.
- Central islands are appropriate if there is adequate width (4.2 m in a 50 km/h zone, or 5.15 m if there is heavy truck traffic). Additional islands between the cycle and traffic lanes are a helpful measure.
- Kerb extensions may be inappropriate but Sustrans (1997) show a small extension, half the width of a parking lane, to prevent a cycle track entrance or exit from being blocked by illegal parking.
- Gateways at the edge of an urban area normally need by-passing. If they are safe for cyclists they are ineffective for motor vehicles.

Where speed humps are used, Sustrans (1997, p 99) say that a sinusoidal design, with smooth transitions, is best for cycles. Such a design should also eliminate the objectionable noise of motor traffic on a speed hump (at least for vehicles travelling within the design speed). Hass-Klau et al (1992) show a sinusoidal design with a height of 120 mm and an overall length of 4.8 m for 30 km/h, or 3.36 m for 20 km/h.

Sammer (1993) reports traffic calming a whole city, in Gratz, Austria: much cheaper than small, piecemeal schemes because the need for signs and paperwork is minimised. Interestingly, Sammer reports lukewarm public support before opening, rising to strong support five months after opening—from 47% to 81% for cyclists and from 29% to 62% for car drivers.

Recommendation:

- Traffic calming designs should be cycle-friendly and should not introduce pinch points. Large schemes tend to be cheaper in the long run (53).

6.13 Cycle streets

Where a cycle route is on a quiet street parallel to a main motor traffic route, cycle provision can be limited to warning signs and measures to prevent the street being used by through traffic. Traffic calming measures may be needed to control the speed of the remaining traffic. Measures to prevent through motor traffic can be of three types.

- Single-point street closures, using bollards, kerb build-outs or both to narrow the street to a 1.5 m cycle track, or 2 x 1.5 m tracks for busier routes.
- One-way streets with provision for contra-flow cycling, arranged so that motor traffic has to turn off the cycle route.
- Two-way streets arranged so that they cannot be used by through traffic. A useful device is a kerb or bollards diagonally across a crossroads, forcing motor traffic to turn but allowing cycles and pedestrians to take any route (Hass-Klau et al, 1992, p 50).

6.14 Cycle lane and track terminations

Cycle lanes or tracks must end in a safe place, and should end after a junction rather than before it. A bi-directional track will need special provision for cyclists crossing the road, usually with motor vehicle priority, but other cyclists should not need to slow or stop. Motor vehicle parking at the entrance and exit must be controlled. CROW (1993, pp 220-37) give some creative solutions to the problems of illegal car parking on and at the end of cycle facilities, including well-placed bollards, carriageways too narrow for a car to pass a parked vehicle, and 'anti-parking kerbs' too high for motor vehicles to climb but with gaps allowing easy pedestrian and cycle access. German practice is to use *panel crimper* bollards about 400 mm high: too high for a 4 wheel drive to straddle but too low to be easily seen by a driver illegally parking against them.

Recommendation:

- Develop guidelines on ending cycle facilities (43).

7 Physical measures at junctions

7.1 Introduction

In this section cyclist's problems at junctions are analysed and engineering solutions proposed, based mainly on CROW (1993), Sustrans(1997) and Austroads (1993).

Junctions account for some 42% of fatal injury crashes and 56% of serious injury crashes. A further 14% of fatal and 16% of serious injury crashes are at driveways. Of the thirteen main crash types, 7 are primarily associated with junctions: LB, HA, JA, GC, GB, KA and KB.

7.2 Traffic speed

Traffic speed is crucial in controlling cyclist's safety risks. See 5.2. Several control methods are available for junctions: most help pedestrians as well as cyclists.

- A speed table, raising the junction by about 150 mm, or traffic calming features on the junction approach. See 6.12.
- Narrowing lanes and reducing kerb radii, if necessary with over-run space for large trucks, arranged to discourage use by cars.
- Traffic islands to prevent cutting corners and slow turning traffic.

Recommendation:

- Develop recommendations for controlling traffic speeds at junctions (44).

7.3 Cycle lanes

Standard New Zealand practice is to terminate a cycle lane for a junction (Transit NZ, 1994, figure 3.32), thus removing the protection where it is most needed, although at least one local authority is now starting to carry cycle lane markings through junctions[10].

Cycle lanes should continue through a junction whenever a cyclist can go through with right of way over cross traffic (Sustrans, 1997, figures 4.5, 5.5 etc, CROW, 1993, section 6.2.4). The Danish Ministry of Transport (1994) specifically recommend that cycle lanes be continued across signalised intersections.

Figure 7.1 shows a cycle lane crossing of a minor road, generally following the practice recommended by Sustrans (1997, figure 5.3). Two approach treatments are shown. The main diagram shows a mandatory cycle lane with no parking, switching to an advisory lane—with a contrasting surface—for the junction and its immediate approach. The inset shows parking allowed on the kerb side of the cycle lane and a kerb build-out to control parking close to the junction. The marking system is as proposed in Figure 6.4. Points to note are given below.

- The mandatory cycle lane switches to advisory for the junction and its final approach.

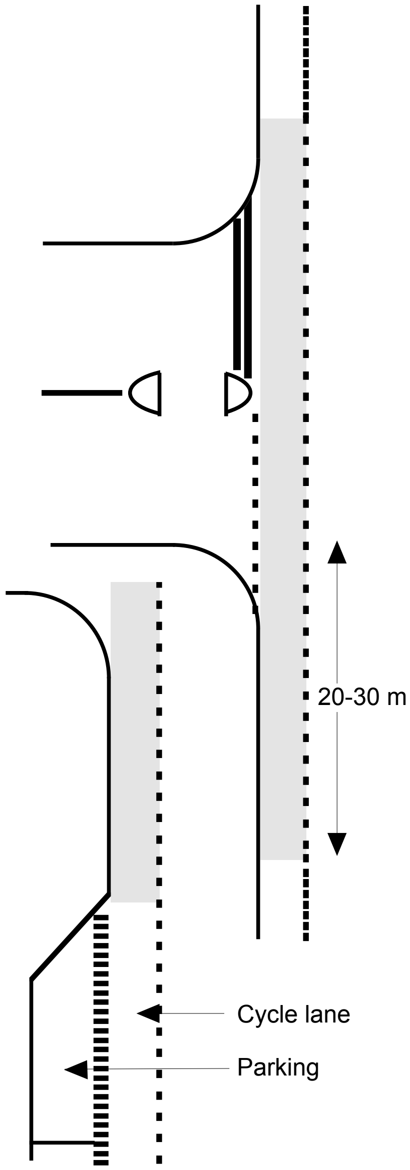


Figure 7.1: Cycle lane crossing a minor junction

Lane markings as proposed in 6.6
See text for comments on the approach length

[10] Alix Newman, Christchurch CC, personal communication

- The cycle lane surface at the junction and approach is in a contrasting colour (grey in Figure 7.1). Red is usual, or cross hatching in white has been used (Ministry of Transport, 1994).
- Kerb radii are reduced as far as possible and a traffic island provided.
- Where kerbside parking is allowed before the junction (inset), the cycle lane is advisory and parking is restricted by a kerb build-out in the junction approach zone, where turning motor traffic is merging with cycle traffic. The minimum approach length given by Sustrans is 10 m (1997, figure 5.3) but CROW (1993) call for 30 m. The Danish Ministry of Transport (1994) specify 20–30 m.

The ten metres of advisory lane on the approach, recommended by Sustrans, does seem short. A cyclist travelling at 20 km/h will cover that distance in 1.8 seconds, a left turning driver often in less, giving little time for merging with cyclists before the junction. The CROW or Danish Ministry of Transport recommendations seem more appropriate here.

Several effects of this layout can be expected.

- Turning traffic speeds are reduced by the smaller kerb radii and traffic island, giving more time for crash avoidance and reducing the severity of residual crashes. All crash types and all modes are affected, and the islands also help pedestrians directly.
- The presence of the cycle lane is obvious, reminding all road users to look out for cyclists.
- Drivers running parallel to the cycle lane and turning left are unable to (legally) move into the cycle lane more than 20–30 m before the junction, and are reminded of their obligation to give way to cyclists. The advisory lane before the junction means that motor vehicles are able to move into the cycle lane before turning and do not have to look out for cycles and turning traffic at the same time: see 7.7.

Recommendations:

- Continue cycle lanes through junctions whenever cycles have priority over cross traffic, including signalised junctions (27).
- Reserve a suitable road surface colour for highlighting cycle lanes where needed (28).

7.4 Cycle tracks

Where a cycle track crosses a road there are several options.

- A conventional crossroads, with priority to whichever route is busier.
- A with-flow cycle track parallel to a road 'bent in' to form a cycle lane at a minor road crossing.
- A with-flow, contra-flow or two-way cycle track parallel to a road 'bent out' to make a semi-separate crossing.
- Traffic signals: see 7.8.
- Grade separation.

Priority can be to either the cycle track or the road. If cycles have priority a speed table is needed to slow road traffic. A traffic island or traffic signals are options for heavy traffic.

Some New Zealand junctions provide a special island for a cyclist's crossing, with an S-bend within the island. The design is shown in National Roads Board and Urban Transport Council (1985, figure 4.3). The intention is presumably to slow cycles and turn them to face oncoming traffic, in the interests of safety, but a likely practical effect is that the cyclist is distracted by concentrating on balance on what is usually a very sharp S-bend. Sustrans (1997, figure 5.11) recommend such a chicane only if the cycle route is on offset cross-streets, and then recommends an island at least 3 m wide to allow adequate space for turning.

A one-way cycle track parallel to a road can be 'bent in' to form a cycle lane for a road junction (CROW, 1993, figure 6.18). Bending in should be complete at least 30 m before the junction, to allow merging of left-turning traffic (20–30 m in Danish Ministry of Transport, 1994). CROW (1993, figure 6.19) suggest that neither bending in nor bending out is needed if the gap between track and road is 1.0 m or less. The Danish Ministry of Transport (1994) use a similar approach at a signalised intersection. See 7.8.

Two-way cycle tracks need special care because of the risk to cyclists travelling in the 'unexpected' direction (Räsänen and Summala, 1998).

A one-way or two-way cycle track parallel to a road can be 'bent out' for a minor road crossing. See Figure 7.2. This arrangement is described as a compromise by CROW (1993, p 161). Traffic turning left off the main road has enough space for most vehicles to wait for cycles off the main road, but the cycle crossing is still seen as part of the road junction and the cycle priority is emphasised. CROW recommends a minimum cycle track radius of 30 m for the bend-out, or 60 m for a two-way track. Sustrans (1997, p 64) recommends a speed table for the cycle crossing and a maximum traffic flow on the side road of 400 vehicles/h.

The main compromise of a bent-out cycle track crossing is in the separation between the crossing and the major road. It must be large enough to take a car waiting to enter the major road, but not large enough for a car entering the minor road to reach too high a speed before crossing the cycle track. The result is a separation too short to leave space for a large truck waiting to enter the major road but this does not seem to be a problem in practice.

In a few cases separation between cycles and motor traffic will require grade separation. This is undesirable because of cost and frequently problems for cyclists, including indirect routes, unnecessary exposure to weather on an overpass, and social safety. Where grade separation is used, Sustrans (1997, figures 5.17 & 5.18) give appropriate standards.

- Minimum subway height 2.4 m.
- Minimum bridge handrail height 1.4 m.
- Maximum ramp grade 5%, but 7% is tolerable if space is tight and measures such as staggered barriers are used to control cycle speed.
- Steps at a maximum angle of 26.5° (going:rise = 2:1) and provided with a half-round channel at the side for wheeling a cycle. The minimum channel width should be 50 mm, and the minimum separation from the side wall 200 mm.

Subways are usually best for cyclists: they minimise grades and weather exposure, but for social safety the subway needs to be wide and an approaching cyclist needs to be able to see right through.

Recommendations:

- Develop standards for cycle track crossings (38).
- Abandon the practice of putting a chicane in a traffic island used by cyclists (39).

7.5 Cycles turning left

Turning left is seen as the easiest of manoeuvres but has its dangers. Problems include squeezing or impact by a motor vehicle taking up a left side position before turning left (movement code AC or FA, cycle 2nd vehicle), or being struck from the right during the turn (KA, cycle 2nd vehicle). Movements AC and KA together account for about 5% of fatal and 3% of serious injuries.

Crashes of movement code FA which are at a junction account for a further 4% of fatal and 1% of serious injuries, but many of these will be associated with turning right or going straight ahead.

Helpful measures include the following.

- Slow turning traffic. Any road narrowing needs care as it may introduce a pinch point at or just before the turn.
- Provide a short length of cycle track at the apex of the left turn: in effect a short cut across the corner. This may also help pedestrians with road crossing: it is often easy if the kerb radius is being reduced.
- Allow a free left turn for cyclists.
- At traffic signals, use an advanced stop line for cycles. See 7.8.
- At a private entrance ensure that the footpath and any cycle track form a speed table for traffic entering or leaving.

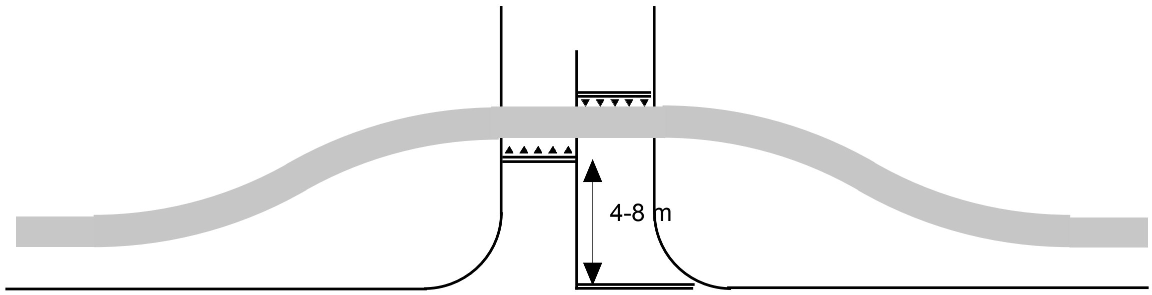


Figure 7.2: 'Bent out' cycle track crossing a minor road

Adapted from Sustrans (1997) Figure 5.5

7.6 Cycles turning right

Turning right is generally the most difficult manoeuvre for a cyclist, particularly on multi-lane roads. In New Zealand five of the most common cycle crash movement codes are associated with the cyclist turning right (LB and JA, cycle 2nd, AA, cycle key and GC, and KB, cycle 2nd). U-turns (MB, cycle 2nd) may in fact also be right turns. These together account for about 29% of fatal and 24% of serious injuries.

There are three broad techniques available to cyclists at uncontrolled junctions.

- Behave as a vehicle. Move into the centre of the traffic lane before the junction, change lanes if necessary, and turn in the same way as a motor vehicle. If necessary, wait for oncoming traffic in a right turning lane or close to the centre line.
- Behave as a vehicle, using the alternative technique of stopping on the left and turning when the road is clear in both directions (LTSA, 1997, p 5.22).
- Behave as a pedestrian. Stop on the left and cross on foot.

Unfortunately a fourth technique is seen only too often, usually by young children: turn right from the left side of the road but without stopping and sometimes without looking behind.

Helpful measures for cyclists turning right include the following.

- Through traffic slowed.
- Grade separation or an entirely separate route.
- Special 'weaving lanes' for right-turning cycle traffic, allowing cyclists to cross parallel traffic one lane at a time to reach the correct position for a turn (CROW, 1993). Not recommended for junction approaches where traffic is fast.
- Special options at traffic signals: see 7.8.
- Reduce traffic lane widths (thus reducing both vehicle speeds and distance across the junction) but avoid creating a pinch point for cyclists.

At major junctions it may be helpful to provide more than one method of crossing, to cater for both experienced and inexperienced cyclists.

McClintock (1992, p 79) makes the point that cyclists usually cannot signal while braking, which may be relevant in junction design if the approach is downhill.

7.7 Cycles not turning

The dangers of cycling straight through a junction come from parallel traffic turning left (GB, cycle key) or preparing to turn (AC, cycle second or AA, cycle key), or crossing or turning traffic coming from the right (HA, LB, both cycle key). These movement codes together account for about 18% of fatal and 26% of serious injury crashes.

Where a cycle lane is continued across a junction, as recommended in 7.3, drivers approaching from the same direction but turning left may have to look out for traffic on all legs of the junction, including cyclists behind and on their left. (If they hit a cyclist going in their direction, the crash may be recorded as GB or AC, or perhaps AA if the cyclist is considered to have moved to the right to go through the junction) Forester (1994, p 102) identifies the problem and describes the cyclist as being outside the driver's *arc of vigilance*, but his only solution is more proficient cyclists behaving as motor vehicles. CROW (1993, pp 158–66) offers several solutions.

- A cycle lane or track as shown in Figures 7.1 and 7.2.
- Weaving lanes on the junction approach as shown in Figure 7.3. This arrangement is satisfactory only if vehicle speeds can be kept below 30 km/h.
- Traffic signals with an advanced stop line for cyclists.
- Traffic signals with a separate phase for cyclists.

None of these solutions seems adequate for present day conditions on the busier junctions in New Zealand, where traffic is fast, cycle traffic light, and many junctions have large kerb radii. Transit NZ (1994, Figure 3.23) demonstrate the problem but fail to offer a solution. A solution is given in Austroads (1993, Figure 4.10) but it is no more than the weaving lanes rejected by CROW.

I tentatively suggest the following options.

- Use weaving lanes on the junction approach, with traffic speed reduced as far as possible (reduced slip lane radius, a speed table at the junction, a speed cushion before the weaving section, etc). See Figure 7.3.
- Use a widened advisory cycle lane at the junction approach, doubling as a left turn lane for motor vehicles but with cycle priority. See Figure 7.3.
- Use a combined solution, with cyclists given the choice of one of the above options or dismounting and crossing the road as a pedestrian.

A helpful general rule would be to allow cyclists to go straight ahead from a left turn only lane, as used in Basle (McClintock, 1992).

Recommendations:

- Allow cyclists to go straight ahead from a lane that is left turn only for general traffic, unless specifically prohibited (29).
- Review options for heavy left turning traffic crossing a cycle lane (40).

7.8 Traffic signals

A simple cycle lane at traffic signals is unsatisfactory because cycles are hidden from the drivers of large trucks turning left and have no provision for turning right. Indeed, the layout makes turning right more difficult (except as a pedestrian, with substantial

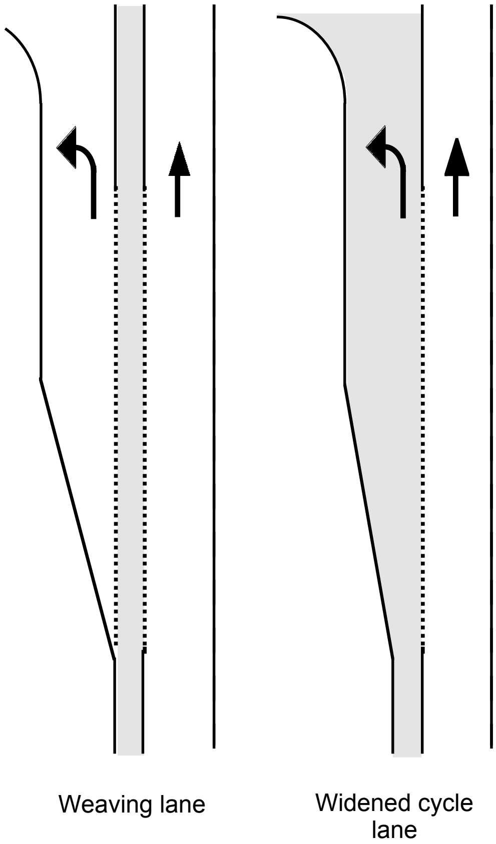


Figure 7.3: Options for heavy left-turning traffic

Weaving lane adapted from CROW (1993, figure 6.10)

delay), by encouraging drivers to expect that cyclists will stay in the cycle lane.

The most usual special provision for cycles at traffic signals is an advanced stop line. CROW (1993, figure 6.28) recommend that the stop line for motor vehicles be set back by 4–6 m and the space reserved for cycles, with a cycle symbol 2.75 m long. See Figure 7.4, which show an advanced stop line with a reservoir for cyclists turning right. The cycle reservoir should be coloured (Ryle, 1996, Sustrans,1997, figure 5.12). The layout is satisfactory for up to three traffic lanes on the approach and for unidirectional motor traffic flows of up to 1000 vehicles/h. Sustrans (1997) says there is no evidence that advanced stop lines reduce saturation traffic flows. Wheeler (1993) suggests that this is because the traffic flow is cycle-free but the Danish Ministry of Transport (1994) says that the signal timing can be reset to allow for the relocated stop lines. Cyclists do not need separate signal heads (Ryle, 1996). A central cycle lane on the approach is helpful to right turning cyclists if traffic is heavier than 200–300 vehicles per lane hour (Sustrans, 1997). Ryle (1996) recommends a central approach where there is heavy left turning motor traffic, although this does not solve the problem of crossing a fast left-turning traffic stream. Austroads (1993, figures 4.9 and 4.11) show a similar arrangement but with no reservoir and the cycle lane advanced by only 2.0 m. The Danish Ministry of Transport (1994) recommend 5.0 m.

Aggernaes (1993) says that advanced stop lines in Sweden reduced cyclist's risk at traffic signals by 35%.

Other approaches at traffic signals are possible.

- Separate one- or two-way cycle tracks on the junction approach with a separate phase of the traffic signals (Sustrans, 1997, Figures 5.13 and 5.14). Sustrans show a track for cyclists turning right marked across a junction using *elephant's footprints:* lines with a width and stripe of 400 mm (these elephants have square feet).
- For a T junction, cycle by-passes for movements that do not conflict with motor traffic movements: straight through opposite the ending road, or turning left from the through road (Sustrans, 1997, figure 5.15).
- A 'hook turn' (Austroads, 1993, p 35), where the cyclist keeps to the left through the junction, stops in front of traffic waiting to cross from left to right and then crosses when the lights change. Problems needing care include keeping cyclists clear of pedestrian crossings and left-turning motor traffic expecting the cyclist to also turn left. McClintock (1992, p 27) says that advanced stop lines may not be appropriate at complex junctions and a hook turn may be the best alternative.
- Separate signal phases for cyclists (CROW, 1993, fig 6.3), or cyclists allowed to share an all-pedestrian phase (Barnes dance).

The Danish Ministry of Transport (1994) use a solution to the problem of motor vehicles turning left across a cyclist (GB) at traffic signals, which they

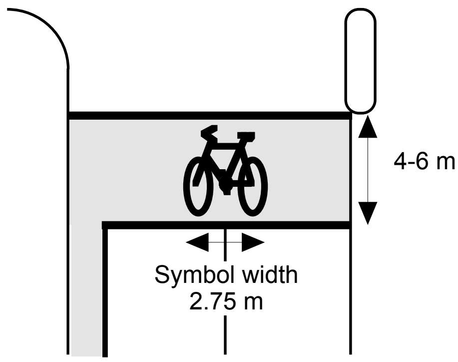


Figure 7.4: Advanced stop line at traffic signals

Adapted from Sustrans (1997, fig 5.12)

say reduces the incidence of this type of crash by 90%. See Figure 7.5. The Ministry generally prefer a with-flow cycle track at footpath level as a mid-block solution, but bring it down to road level 20–30 m before the junction, visually narrow it from 2.0 m to 1.1–1.7 m (depending on capacity requirements), and place the cyclist's stop line 5.0 m ahead of the motor vehicle stop line. A reservoir can be used if cyclists need to turn right. This solution achieves the results of a 'bent-in' cycle track but without bending.

An ingenious touch in a photograph in Danish Ministry of Transport (1994) is is a thorn hedge about 1.0 m high, to the left of the cycle lane: an effective parking deterrent.

Recommendations:

- Introduce guidelines for advanced stop lines for cycles at traffic signals (41).
- Investigate the introduction of 'hook turns' as an option for cycles (42).

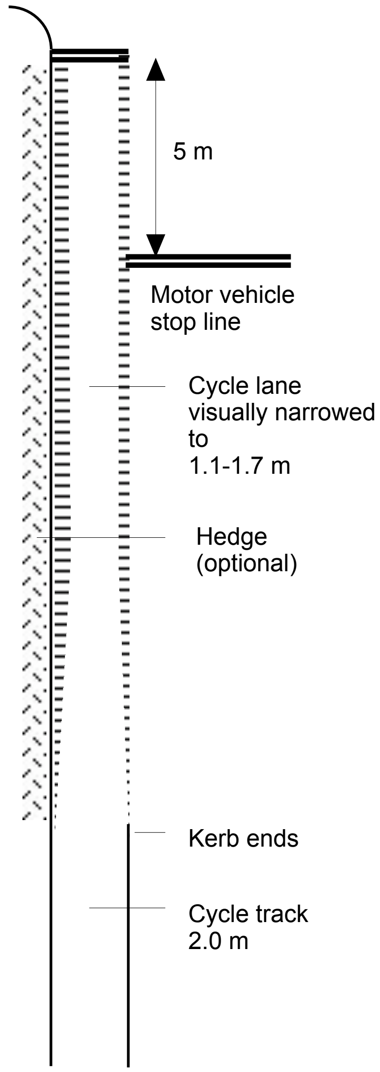


Figure 7.5: 'Bent in' cycle track at traffic signals

After Ministry of Transport (Denmark)

7.9 Roundabouts

Roundabouts are dangerous for cyclists and large multi-lane roundabouts worst of all. See 4.17. The most common roundabout crash type is a motor vehicle entering and failing to give way to a cyclist already on it (movement code LB or HA). A lesser risk is of the cyclist being hit on leaving the roundabout (GB or AC).

In the Netherlands single lane roundabouts with radial approaches have become popular (Schrank and van Munchen, 1994). The radial approach forces drivers to enter at low speed. Such roundabouts can easily handle 2000 vehicles per hour, plus several hundred cyclists. Outside diameter is normally 30 m. Cyclist's crash reduction is about 44% (compared with a conventional roundabout), or 90% with a separate cycle track.

Helpful measures for cyclists include the following.

- Avoid using a roundabout: Stop signs or traffic signals are good alternatives.
- Use small, single lane roundabouts with splitter islands and plenty of deflection, to keep traffic speeds down. CROW (1993, pp 184, 185) recommend a road width of no more than 5 m on the roundabout, with a core diameter of less than 25 m. A recommended layout (CROW, 1993, figure 6.31) shows a core diameter of about 15 m. If necessary large trucks can be allowed to go over a collar forming the outer part of the core at low speed, but it must be arranged so that cars drivers can see the collar clearly but cannot safely cross it at speed.
- Provide a separate cycle route or grade separation at the junction.
- Provide a cycle track or a shared cycle-pedestrian path around the outside of multi-lane roundabouts. This approach is undesirable because of delays to cyclists, but is recommended in the Netherlands for traffic levels above 800 vehicles/h (Schrank and van Munchen, 1994).
- Use full-time traffic signals on multi-lane roundabouts.

Several European layouts incorporate cycle lanes within the roundabout but these cannot be recommended in New Zealand, at least until greater experience has been gained overseas and local cycling has become better established.

Recommendations:

- Develop cycle-friendly roundabout designs (36).
- Design all new roundabouts to cycle-friendly standards, or provide alternative routes (54).
- Review all existing roundabouts for cycle-friendliness and redesign or by-pass as needed (55).

7.10 Stop control

A useful traffic control device in North America is the four way stop. Traffic on all four legs of a junction is required to stop before proceeding through the junction. The device is rare in New Zealand, although examples can be found[11]. It is cheap and effective, but for cycles it has the disadvantage of requiring a stop. This is inconvenient for a vehicle with very low power and introduces a minor safety problem: the greatest risk of falling off is when starting and stopping. In Switzerland the city of Basle has been experimenting with minimising the cyclist's need to stop by allowing cyclists to treat a 'Stop' control as a 'Give Way', apparently with some success (McClintock, 1992, p 34).

Recommendations:

- Consider wider use of the 4 way stop (30).
- Consider allowing cyclists to treat a Stop sign as a Give Way (31).

[11] There is one at Cuba Street and Abel Smith Street in Wellington

8 Discussion of engineering measures and implementation

8.1 Introduction

This section considers the likely effectiveness of cycle engineering measures and likely options for their adoption. Discussion of specific measures is in Sections 5, 6 and 7, where proposals from the chosen overseas standards are compared.

8.2 Cultural background of standards

Assessing the effectiveness of the measures proposed—and predicting their effectiveness in New Zealand—needs an appreciation of their background. The three main source documents used have very different cultural contexts.

CROW (1993)

The CROW manual is—from internal evidence—not a radical departure from earlier Dutch design standards. Some disagreement still exists and there is a reference (p 80) to unsatisfactory practices used by another organisation, but there seems to be general agreement on the broad concepts of road space allocation and safe cycle provision. Some details are inappropriate in New Zealand, such as the requirement for a 25 m horizontal section after each 5 m of vertical rise (CROW, 1993, p 119).

Sustrans (1997)

The Sustrans manual is new (first edition 1994), and intended specifically for the long distance cycle routes of the UK National Cycle Network. There is little apparent background of similar standards in the UK, although The Bicycle Association (1996) take a similar but less detailed approach. Sustrans draws heavily on the CROW manual but is much more radical in a UK context than the CROW manual is in the Netherlands. Sustrans standards are still not generally accepted in the UK: some facilities are clearly substandard and are marked as such on Sustrans route maps (Wood, 1997). Simple improvements would have been possible in two places seen. A Sustrans engineer said that this is frequently the case: no agreement had been reached with the local authority.

Austroads (1993)

Austroads 14 is a better fit into current Australasian roading practice, not least because it is part of a widely used set of standards. However, it gives less safe cycle facilities. In New Zealand it has been adopted by at least one local authority, Palmerston North, and Transit New Zealand have shown interest. It is currently being revised, with a New Zealand representative (Alix Newman, Christchurch City Council) on the panel. The latest draft (Austroads, 1998) still includes unsatisfactory practices.

While all three standards are more or less accepted in their respective countries, it does not follow that they would be acceptable in New Zealand.

8.3 Accepted practice

Acceptance of high quality cycle provision is almost complete in the Netherlands and high in Germany and Denmark, but much lower in the UK (Wood, 1994, 1997), and if anything lower still in New Zealand. The overall proportions of trips made by cycle, given by the Royal Commission on Environmental Pollution (1997, p 61), display the differences: 11% in Germany, 18% in Denmark and 27% in the Netherlands, but less than 2% in the UK. The proportion in New Zealand is 3.7% (MoT, 1992).

Cycle provision in New Zealand seems less common and less satisfactory than even in the UK (Wood, 1994, 1997). What facilities exist are too often well below the minimum standards of Austroads 14, but this should not be a surprise after so many years of neglect. Baier (1996) reports similar problems with early facilities in Germany. However, note McClintock's warning (see 5.7) that poor facilities may be worse than none.

Technically, the best approach in New Zealand might well be to adopt the Sustrans standard, or develop a New Zealand standard based on the three manuals used in this study. However, in practice the Austroads standard is more familiar and might be a better option if its failings can be overcome. Principal areas where the Austroads standard needs improvement are summarised in Table 8.1, which also comments on the 'blue book' (National Roads Board and Urban Transport Council, 1985).

Whatever documentation is used, the standard of cycle provision should be as high as possible. This will mean regular review and amendment in the first few years, as improved standards become more acceptable. This process will take time but needs to be completed as quickly as practicable. Facilities built to the present low standards are too often a waste of money, to say nothing of the cost of unnecessary deaths and injuries in the mean time.

Recommendations

- Adopt a national cycling strategy (5).
- Adopt or develop a good quality cycle standard for New Zealand. Austroads 14 will need revision (Table 8.1) before it is adequate (35).

8.4 Effectiveness of measures

The likely reduction in cycle crash numbers from cycle-friendly provision is discussed in 5.6. I suggest that a good standard should achieve a 60% reduction in fatal and serious injury crash numbers, based on studies of UK and European practice.

If this is reasonable in the UK, what features of New Zealand roads, road users and road legislation might affect a comparison with the UK?

- The most obvious difference between UK and New Zealand practice is the rules for giving way at junctions. I suggest (in 11.6) that New Zealand rules can be difficult to interpret and the speeds they encourage are an important problem. If this is correct the potential benefits of controlling speeds are greater here than in the UK, and the assumed benefits of traffic calming may also be greater.
- Similarly, New Zealand crash rates are high compared with the UK, both for cyclists (see 9.5) and overall. UK death rates are less than half of New Zealand figures, on a both a population and a vehicle numbers basis (LTSA, 1994). In this case the link to greater benefits from traffic calming is unclear because of the high proportion of rural road deaths in New Zealand.
- The response of New Zealand drivers to programmes and physical measures might differ from the response of UK drivers but no specific guidance is available.

8.5 Cycle facilities and cycle numbers

Increased cycle numbers in New Zealand cities are associated with reduced cyclist's risk. The overseas evidence is that this is because other road users become used to looking out for cyclists (see 4.2). However, there is the possibility that the New Zealand data is also reflecting physically safer conditions in those cities with higher numbers of cyclists; predominantly Hamilton, Nelson, Palmerston North and Christchurch.

The dominant effect will be cycle numbers, because cycle facilities are generally poor, even in the most cycle-friendly New Zealand cities. All of the following are rare or absent in New Zealand.

Table 8.1: Summary of main weaknesses of existing standards used in New Zealand

Paragraph numbers refer to this study

Para-graph	Feature	Austroads (1993)	NRB & UTC (1985) ('Blue Book')
6.5–6	Lateral clearance	No special limit on motor traffic speed, separation distance varies with moor vehicle speed if cycle/ motor traffic heavy.	No special limit on motor traffic speed, separation distance varies with motor vehicle speed and density. Separate facility preferred (curve)
	Min width 1.5 m	Min width 1.0 m	Min width 1.2 m
	Parking provision	No restriction	No restriction
	Cyclist's protection independent of cycle numbers	Not covered	Protection dependent on numbers
6.7	Advisory/mandatory lanes	Not covered but implicit in diagrams	Not covered
6.9	Track/road separation	Restricted coverage	Implicit only
6.15	Lane/track ends	Not covered*	Not covered
7.3	Lane line through junction	Restricted coverage*	Mentioned
7.7	Weaving lanes	Covered, high speeds accepted*	Not covered
7.8	Advanced stop line with reservoir	Covered as alternate, length inadequate	Advanced stop line only
7.9	Roundabouts	No mention of small, single-lane Multi-lane permitted	No mention of small, single lane Avoid or segregate

* Improved in Austroads (1998)

- Appropriate use of cycle lanes (Section 6.6).
- Adequate marking of cycle lanes (6.8).
- Cycle lanes marked through junctions (7.3).
- Advanced stop lines with reservoirs for turning right (7.8).
- Off-road routes with proper provision at junctions (7.4).
- Cycle provision in traffic calmed areas (6.12)
- Cycle provision at roundabouts (7.9).

8.6 Specific Measures

The fit between engineering measures and identified problems is far from accurate. There are large benefits to cyclists from cycle-friendly roading design, but the effectiveness of any particular measure is much more difficult to quantify. A preliminary and subjective assessment is given in Table 8.2 (next page). Further comment is made in Sections 5, 6 and 7.

8.7 Future cycling risk

Estimated crash reductions are to 40% of present levels due to good facility provision (see 5.6), and to an average of 40% of present levels due to having more cyclists on the roads (see 4.2). Combining these figures gives a possible future risk at 16% of present levels, or about 6 times safer than at present. This is broadly the same as present-day risks in the Netherlands (see 9.5), suggesting that the figures are reasonably plausible. It is also broadly the same as the present-day risk of motor vehicle use: see 9.3.

8.8 Implementation

Implementation of cycle-friendly policies will need commitment, funding, effective standards and a framework for evaluation of cycle facilities (Sharples, 1995). These in turn will require approved cycling strategies at national, regional and local levels. Any framework for evaluation will inevitably use cost-benefit analysis, but must also recognise the need for a network of safe cycle routes.

All this is fantasy unless there are concrete reasons for new policies, so costs, legal issues and a new vision are discussed in the following sections.

Recommendation:

- Develop a framework for evaluation of cycle facilities, using cost-benefit analysis but also recognising the equity issues of ‘no-go’ areas for cyclists (9).

Table 8.2: Subjective assessment of benefits to cyclists, by movement code

Para No	Movement code / Measures	FA	LB	HA	JA	EA	AA /AC /AF	GC	GB	KA /KB	MB	Head -on	Child
	Cycle lanes and driveways												
6.6	Between junctions	o	-	-	-	√	√	-	o	√	o	o	√
6.7	Critical width design	√	-	-	-	√	o	-	-	o	-	-	o
6.8	Advisory/mandatory	o	-	-	-	√	√	-	√	√	-	o	√
6.10	Bus/cycle lanes	√	-	-	-	o	o	-	-	o	-	√	o
4.19	Road surfaces	o	-	-	-	√	√	-	-	-	-	-	o
	Cycle tracks and driveways												
6.9	Beside road	√	x	-	x	√	√	o	x	o	-	√	√
6.9	Off road	√	o	-	-	√	√	√	√	√	√	x	√
	Junctions (not driveways)												
7.3	Lane thro junction	o	√	√	√	-	o	-	√	√	-	-	√
7.4	Bent in crossing	o	√	√	√	-	√	-	√	√	-	-	√
7.4	Bent out crossing	√	√	√	√	-	√	-	√	o	-	-	√
7.4	Grade separation	√	√	√	√	-	√	√	√	√	√	x	√
7.5	Left turn protection	-	-	-	-	-	√	-	√	√	-	-	√
7.6	Right turn protection	o	-	-	-	-	o	√	-	-	o	o	o
7.7	Straight through protection	√	√	√	-	-	√	-	√	-	-	-	o
7.10	Four way stop	-	√	√	√	-	√	√	√	√	-	-	√
6.14	Lane/track endings	√	-	-	-	√	√	o	o	o	-	-	o
	Traffic signals												
7.8	Advanced stop lines	o	-	-	-	-	√	√	√	-	-	-	o
7.8	Separate bike phase	-	√	-	-	-	√	√	√	-	-	x	o
	Hook turn	-	√	-	√	-	√	√	x	-	-	-	-
	Control traffic speed/flow												
5.2	Between junctions	√	-	-	-	√	√	-	-	√	√	o	√
7.2	At junctions	o	√	√	√	-	√	√	o	o	o	-	√
6.5	Lateral clearance	√	-	-	-	√	√	-	-	o	-	-	√
6.11	Pinch points	√	-	-	-	√	√	-	-	-	-	-	√
6.12	Traffic calming	√	√	√	√	√	√	√	√	√	√	o	√
6.13	Cycle streets	o	o	o	o	o	o	o	o	-	x	-	√
5.5	Safe routes to school	o	√	o	√	-	√	o	√	o	o	-	√
	Roundabouts												
7.9	Cycle-friendly	o	√	√	-	-	o	-	o	o	-	-	o
7.9	Track outside	o	√	x	-	-	o	-	o	o	-	-	√

√ Major benefit — - Little or no benefit
o Minor benefit — x Disbenefit

Note that this table is sensitive to assumptions: Traffic signals are assumed to be modified as shown, not new signals.

9 Costs and Benefits

9.1 Introduction

In this section the costs and benefits of cycle provision are explored.

The present cost of reported cycle crashes can be established moderately accurately, the reportable but unreported crashes less so and the non-reportable crash costs less accurately again.

Cycle facility construction costs and benefits are also difficult to quantify. The principle used here is to assume general cycle-friendly treatment of urban areas, simply because of the difficulties of setting other boundaries. In reality treatments will be more local and will bring greater benefits, because the less attractive schemes will be dropped.

An important benefit missing from this section is the health gains from greater use of cycles. This is partially covered in 9.6 but Hillman (1997) says that health benefits outweigh crash disbenefits by 20:1, or by at least $4.0 billion/year if this figure applies in New Zealand. However, benefit is difficult to capture in monetary terms and may even be a disbenefit in national terms: longer lives mean larger pension pay-outs (Swinburn, 1997: oral reply).

9.2 Cost of reported cycle crashes

Costs for individual crashes, including external costs, are given in MoT (1996). The relevant figures are shown in Table 9.1. Property damage in cycle crashes will be much less than for motor vehicle crashes and is ignored.

Table 9.1: Costs of injury crashes

From MoT (1996)

	Total	Property damage ignored
Fatal injury	$ 2 600 000	$2 560 000
Serious injury	$ 220 000	$218 000
Minor injury	$6 000	$2 800

Taking the mean number of crashes over the period 1988–96 as the current average gives the following costs.

Fatal crashes:
166 for 1988–96 = 18.4 fatalities /year
Cost = 18.4 x $M 2.56 — $47 M

Serious injury crashes:
1913 for 1988–96 = 213 /year
Cost = 213 x 218 000 — $46 M

Minor injury crashes:
6466 for 1988–96 = 718 /year
Cost = 718 x 12 800 — $9 M

Total reported crash costs — $102 M

9.3 Total cost of reportable cycle crashes

There is very little information available on the cost of unreported crashes. Cambridge et al (1991, table 51) give a reporting rate for reportable crashes causing injury of 42% for the last 8 months of 1989 and say that this is similar to the 50% obtained by Bailey (unpublished), using a smaller sample. The LTSA say that reporting rates are generally 40–60% in New Zealand and that cyclists are at the the poor end of the range but serious injuries are a little better: say 40% for minor injuries and 50 % for serious injuries[12]. On this basis annual unreported injury crash costs are:

Serious injury:
[(213/0.5) - 213] x $ 218 000 — $46 M

Minor injury:
[(718/0.4) - 718] x $ 12 800 — $14 M

Subtotal: reportable but unreported crash costs — $60 M

Plus reported crash costs (9.2) — $102 M

Estimated total annual cost: reportable cycle crashes — $62 M
Round to — **$160 M**

On this basis the annual totals by degree of injury are:

Fatal injury
18.4 injuries/year — $47 M

Serious injury (rounded)
426 injuries/year — $90 M

Minor injury (rounded)
1800 injuries/year — $23 M

ACC data ought to provide a useful cross-check but does not distinguish between levels of injury. ACC use a year ending on 30 June, making direct comparison with LTSA data difficult. A request for 3 years of information produced two complete years (ACC, personal communication), summarised in Table 9.2. There are large differences between the

[12] Paul Graham, LTSA, personal communication

two years of data but the mean value of injury numbers involving a motor vehicle is 97% of the estimate above: near enough.

Recommendation:

- Ensure that LTSA and ACC data can be compared on the same basis (8).

9.4 Cost of non-reportable cycle crashes

Cambridge at al (1991) give a figure for the reporting rate of non-reportable crashes but there is a contradiction here. Such crashes will tend to be eliminated from the database so what is being measured is the efficiency of the weeding process as much as the underlying reporting rate.

Armstrong (1994) gives totals for all cyclists seen by a hospital (Christchurch: 1991–94). He gives no breakdown by serious or minor injury but instead gives outcomes: Discharged, Outpatient, Admitted, Died and Other. The proportions for all groups except 'Died' show very little variation, regardless of whether or not a car was involved. The largest variation is some 7%, in 'Discharged'—the least severe category. It follows that the cost per cyclist injured of reportable and non-reportable injuries will be about the same.

Table 9.2: New entitlement claims involving a cycle

From ACC data

	1995/6	1996/7	Mean
Motor vehicle	2377	1944	2160
On-road, non-motor vehicle	4228	2755	3492
Off-road, non-motor vehicle	8431	9115	8773
Total	15 036	13 814	14 425

It is possible that some non-reportable injuries are fatal: these could only be traced through medical or coroner's records.

Data for Christchurch for 1991–93 was supplied by Armstrong (personal communication), but unfortunately there is no clear distinction between, for example, falling and hitting the road and falling and hitting the ground. Some cases are clear but many are not and it seems safer to use ACC data. ACC give several categories of off-road cycle injury so I assume that non-transport crashes are excluded. Using ACC data:

Number of on-road, non-reportable crashes
(1995/6 and 1996/7 mean) = 3492

Serious injuries:
3492 x (426/2226) x $ 218 000 — $145 M

Minor injuries:
3492 x (1800/2226) x $ 12 800 — $36 M

Total cost of non-reportable injuries — $81 M

Round to — **$180 M**

Recommendations:

- Investigate methods of reducing the cost of non-reportable crashes (72).
- Check the possibility that some non-reportable crashes are fatal (73).

9.5 Cyclist's risk

The annual distance cycled in New Zealand was 350 million kilometres in 1989–90 (MoT, 1992). The number of fatalities in those two years was 20 and 27. Stabilising the numbers by including one year either side and taking an average for 1988–91 gives 22.2 deaths/year, so the risk of fatal injury while cycling was then around:

(22.2/350) x 1000 = 63 /bn km

Round to 60 fatalities / bn kilometres

The average cost of reportable cycle crash risk was around:

$M 160 /350 million km = 46 c/km (see 9.2)

Round to 45 cents/ km

Unfortunately these figures cannot be disaggregated by urban and rural crashes, or by urban area, because MoT (1992) does not contain the necessary data.

The UK fatality rate is 47 per billion kilometres (Royal Commission on Environmental Pollution, 1997). German and Swiss figures for cyclist deaths per million population are substantially lower than the UK (Cyclist's Public Affairs Group, 1996, no figures or dates given). Denmark and the Netherlands have fatality rates rates of 40 and 20 /bn km respectively (see below), and Nolan (1995) gives 62 /bn km for the Philadelphia area.

The UK figure is poor in European terms (Royal Commission on Environmental Pollution, 1994), suggesting that the higher New Zealand figure is poor in international terms.

The New Zealand figures look worse when comparisons are by age: see Figure 9.1, which is compiled from data in MoT (1992) for travel in 1988–89 and all fatalities 1980–96. Other data is from the Danish Ministry of Transport (1993b) for Denmark and Wittink (personal communication) for the Netherlands.

In New Zealand the fatality risk of cycling is seven times higher than in the Netherlands for cyclists aged 25–35 and two or three times higher for cyclists aged 10–19. The 20–24 and 35–39 years age groups are ignored because of small numbers in MoT (1992). For cyclists aged 5–9 the New Zealand risk is 10 times higher than in the Netherlands but this comparison uses less reliable Dutch data.

The disparity of risk between New Zealand and the Netherlands is higher for most age groups than for the overall figures. The likely explanation is a greater proportion of high-risk elderly cyclists in the Netherlands, observable in photographs in CROW (1993). Hillman (1997) says that female Dutch pensioners make a quarter of their trips by cycle: the New Zealand figure must be vanishingly small. Elderly cyclists are a high risk, visible in all three data sets in Figure 9.1. A pedestrian aged 70+ is three times as likely to die from a given level of physical insult as a 15–45 year old (Keall, 1995), but the scale of increase in Figure 3.1 is greater than this, suggesting that declining abilities are also a factor.

Denmark and the Netherlands place very little emphasis on conspicuity or helmet wearing, so if these defensive measures are effective in New Zealand they are concealing an even greater disparity of risk in the cycling environment.

If the risk differences in the 25–35 years age groups are taken as typical, then the smaller differences in the 10–19 years age groups may be because New Zealand cyclists in these age groups are avoiding risk by limiting their choices of routes and destinations. Indeed, all age groups may be doing this: see 4.17.

The New Zealand figures contain large uncertainties due to small samples in the Household Travel Survey (MoT, 1992), which must be borne in mind when making comparisons. For example, the risk peak for New Zealand cyclists aged 20–24 (Figure 9.1) may not be real. The Household Travel Survey gives sampling error estimates for some age groups, but for others—including this one—numbers were too small. Wittink (personal communication) says that the more reliable Dutch exposure figures are subject to errors of about ± 25%, which is broadly comparable with the New Zealand data (Wittink, personal communication).

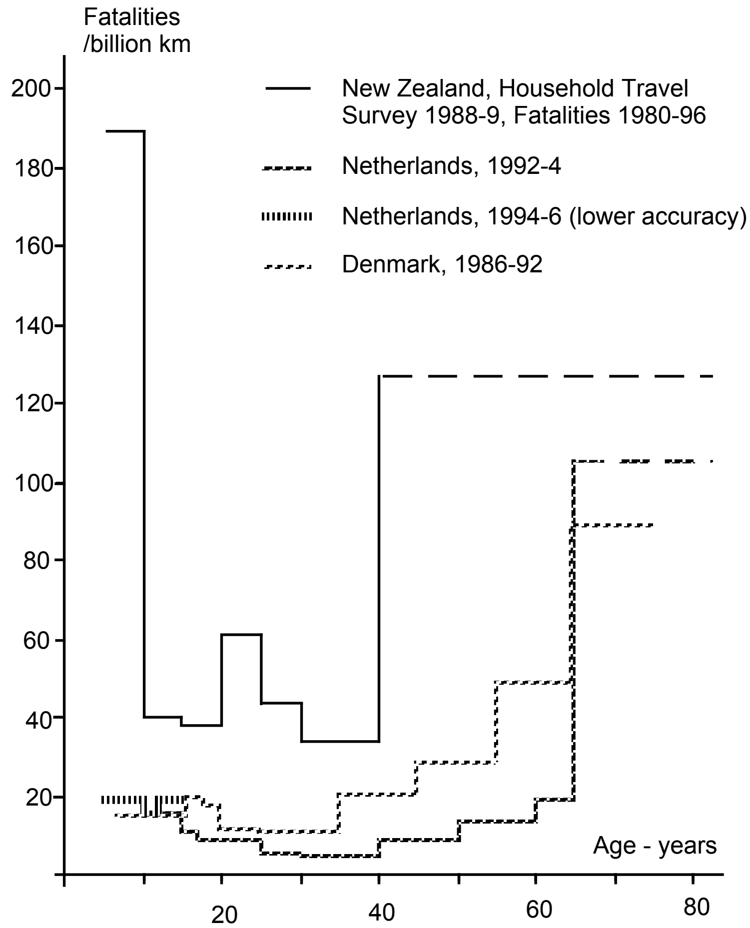


Figure 9.1: Cyclist's risk by age for New Zealand, Denmark and the Netherlands

Wittink (personal communication) points out that a cycle is sometimes safer than a motor vehicle. This can also be shown in New Zealand. The 15–19 year olds face a cycle fatality risk of 38 /bn km (Figure 9.1). Assuming that their serious to fatal injury ratio is the same as in 9.2 , the cost to this age group of fatal and serious injuries can be calculated. The same age group, in motor vehicles, were involved in 610 crashes in 1989 (Household Travel Survey year: no need for long time scales here), with a total of 115 fatal and 687 serious injuries in a total of 690 million vehicle kilometres. The cost of risk for deaths and serious injuries is therefore:

Cycling: $M (38 x 2.56) x 160 / 47 x 1000
33 cents/km

Driving: $M ((115 x 2.6) + (687 x 0.22)) / 690
65 cents/km

The difference will be greater if males and females are disaggregated but smaller if rural and urban use is disaggregated. Overall, a male aged 15–19 will be safer to the community—including himself—when riding a bicycle than when driving a car, and probably also safer to himself only. Wittink's figures show that in the Netherlands even the 25–29 years age group is safer on cycles.

Another form of cyclist's risk is the non-reportable crashes which seem to cost even more than the reportable crashes. Very little is known about these but I suggest that the total cost of non-reportable crashes will not change much with increased cycle use, if facilities are also improved.

- Incidents due to inexperience will increase a little, but the increase will be limited because most people are already learning to ride a cycle. It might be a only a transient effect.
- Incidents due to to being over-adventurous will not increase because the demand for risk taking is already satisfied. Indeed, risk taking by present cycle users may decrease if safer cycling makes other activities more interesting to the high-risk age group.
- Risk-taking on cycles will increase if high-risk age groups transfer from car use to cycling in significant numbers. However, this will be more than offset by a decrease in the cost of risk taking by car drivers.
- Incidents due to poor road surfaces or crowding by a motor vehicle (which is not reportable unless contact is made) will be reduced by better facilities.

Overall, I suggest that increased cycle use should not increase the total cost of non-reportable crashes very much, and the individual risk of non-reportable crashes should fall substantially.

Recommendation:

- Seek to learn more about non-reportable crashes (74).

9.6 Benefits of cycle-friendly provision

The following figures give preliminary costs and benefits, based on treatment of all urban areas, and cycle numbers increasing to 16% of commuter trips (four times the present average: see 5.7). This is equivalent to a total of 1.4 billion cycle kilometres a year.

a) Safer cycling—existing cyclists.
Sixty percent of fatal and 78% of serious injury crashes studied are in urban areas (taken as 50 km/h speed limit or less). Assume that New Zealand risk levels can be reduced by 84%, but with no change in non-reportable crashes.
$ 100 M/yr

b) Safer cycling—new cyclists
Safer cycling and increased cycle numbers will together reduce the average cost of cycling to some 40% of present levels due to improved facilities (see 5.6) and another 40% due to increased cycle numbers (Figure 4.1), or to around 7–8 cents/km overall. This is below the present average cost of car use and implies a marginal cost of cycle use lower than the present cost of car use. A conservative assumption is that there would be no overall benefit. No saving

c) More efficient use of road space
Greater cycle use could reduce or eliminate the need for new or widened urban roads. See 6.4. Assume that 20% of present capital expenditure on new roads (taken as $105 M, average 1992–3 in MoT, 1995) can be saved. $ 20 M/yr[13]

d) Lower personal transport costs
Major benefits are possible for those who can do without a car, or fewer cars, or who cannot afford a car but can take advantage of increased mobility. Unknown

e) More commuters using public transport
This effect is due to providing safe storage for cycles at selected public transport stops, and limited cycle carrying on public transport.
Unknown

f) Better health for those who cycle
The estimated cost of physical inactivity in New Zealand is $162 M/ year (Swinburn, 1997). Assume that cycling could eliminate 20% of of this. $ 30 M/yr

g) Reduced environmental externalities
Assume that half of increased cycling translates into reduced driving, so a billion extra cycle kilometres a year is equivalent to a 500 million vehicle kilometre fall in motor vehicle use. Total annual motor vehicle kilometres are about 31 billion (MoT, 1997a). Annual environmental costs are estimated at $bn 1.38 in MoT (1996), but there may be some double counting. Assume that any double counting is offset by improvements due to avoiding cold running on short journeys.
$ 20 M/yr

h) Encouragement of local shopping
Use of local shops further reduces travel demand. Small branches of large store chains can

[13] (2008) This figure would be much larger today.

now operate competitively (Cairns, 1995) so the saving is not lost in higher prices. Unknown

j) Increased personal safety
More cyclists make streets feel safer and, can actually improve the perceived safety of a street, thus opening up opportunities for access and mobility rather than curtailing it. (Cleary, 1992, p 156). Unknown

Total savings at least $ 170 M/yr

Additional savings would be possible through large scale traffic calming.

m) A 60% reduction in pedestrian deaths and injuries in present 50 km/h areas (see 5.6). Allow present urban (50 km/h) totals of 42 killed, 850 injured (LTSA, 1994), 23 % seriously (ie the same ratio as for reported cycle crashes: see 9.3). $ 100 M/yr

n) Vehicle occupant deaths and injuries reduced 60% in present 50 km/h areas.
Allow present totals of 112 killed, 6500 injured (LTSA, 1994), say 15% seriously. $ 350 M/yr

o) Health gains from increased walking and cycling
See (f) above (assumed savings now total half of current costs) $ 50 M/yr

p) More children walking and cycling to school. This will reduce escort journeys by car. Such journeys are made at peak periods, are often double (because the driver returns home after delivering the children) and are usually short, so the engine is cold and causes disproportionately high pollution. No New Zealand estimate is available for the cost of these escort journeys but their existence is clear from the reduction in peak hour traffic during school holidays. Assume that savings are 25% of the UK lower bound estimate (£ 10 bn, Whitelegg, 1993), adjusted on a population basis. $ 430 M/yr

q) Lifestyle gains from more pleasant urban areas Unknown

r) Urban concentration effects from encouraging short-distance transport. Unknown

s) Lower costs of car use due to greater use of less costly modes. Unknown

Total savings at least $ 930 M/yr

9.7 Costs of cycle-friendly provision

Cumming and Shepherd (1996) give an estimate of Aus$ 70 M for 2000 km of cycle facility in Melbourne, or NZ $41 000 /km. However, they propose cycle lanes almost exclusively—on main roads—and will not achieve the best practice proposed here. Tolley (1989) gives mid-1980s German average costs of DM 400 per head of population for good quality cycle provision, or DM 1400 per head including traffic calming. New Zealand costs will be reduced by lower labour costs, but also increased by lower urban densities and therefore greater road length per head of population. Hopefully these effects will cancel out. However, Hülsmann (1997) also quotes DM 400 per head of population, suggesting that German costs have fallen since the 1980s, as could be expected with increasing experience. The New Zealand dollar and German mark are at present about equal (April1998), so assume that costs in New Zealand would be $ 400 per head for cycle provision and $ 1400 per head for full traffic calming. On this basis, total costs for the cities listed in Table 3.1 (total population 2.02 million), plus a further 490 000 in the smaller centres (Statistics NZ, personal communication), would be:

$1000 M	for full cycle provision
$3500 M	for full traffic calming

There will also be ongoing maintenance costs, taken as 7% of capital cost.

The major 'operating cost' of traffic calming is delays to motor vehicles, but calculations are difficult because MoT (personal communication) have no data on average vehicle speeds. They have by-passed the problem in their studies by calculating fuel consumption by distance (MoT, 1997a).

Hass-Klau at al (1992) quote a reduction from 42 to 30 km/h, or a 40% increase in travel time on the traffic calmed section of the journey. However, not all roads would be traffic calmed, reducing the effect on trip time. CART (c1994) give an average increase in journey time of 11% but the original source is unknown. It is likely to be European and could be sensitive to residential density. I have attempted a crude check by estimating the proportion of journey length that would be in 30 km/h zones in a fully traffic calmed New Zealand city. See Appendix E, which develops a value of 33% of vehicle kilometres on traffic calmed streets in Wellington. However, note that—at least in the short term—this is a gross over-estimate because there is no present political support for traffic calming on this scale.

The figures from CART (c1994) and Hass-Klau et al (1992) are consistent if the proportion of an average journey on traffic calmed city streets is 27.5%. If the traffic calmed proportion goes up to 33% (Appendix E) the increase in travel time will go up from 11% to 12%: the change is small enough to improve confidence in the figures.

In New Zealand MoT (1997a) gives total vehicle kilometres travelled as about 31 billion km/yr (table 5.16), of which about a third is rural use (p 99). Allowing $ 15/h for value of time, the delay costs for a 12% increase in urban journey time are equivalent to some $M 800 /y, assuming an initial average speed of 45 km/h. This would be the delay cost of full traffic calming: cycle provision would have a much lower penalty, say a tenth of this, or $80 M/year.

9.8 Summary of benefits and costs

The costs and benefits of cycle-friendly provision are summarised in Table 9.3. It can be argued that these costs and benefits are so crude as to be meaningless, but three points must be borne in mind.

- Totals for a series of crude estimates are more accurate than they seem because errors will tend to cancel out.
- Several costs have been left out because they are unquantifiable, tending to make the results conservative, although this may be partially offset by double counting.
- These figures are for comprehensive treatment of all the main urban areas (total population 2.5 million), which is unrealistic.

Getting past break-even is good for such a crude approach and the best schemes will have much better returns than shown here. The worst will not be implemented. This is in agreement with overseas experience (Hass-Klau et al, 1992). Safety improvements in York, UK (see 11.5), repaid their capital costs in about 18 months (Cyclists's Public Affairs Group, 1996).

Table 9.3: Summary of costs and benefits of city-wide cycle-friendly provision

Note that selecting the more effective schemes will substantially improve these returns

		Benefits $M/yr	Costs $M/yr
Cycle provision only		Benefits $M/yr	Costs $M/yr
Cost of traffic delays (9.7)			80
Crash costs for new cyclists (9.6 (b))			–
Maintenance costs, 7% of capital (9.7)			70
Annual benefits (from 9.6)		170	
Gross annual benefit		20	
Capital cost (9.7)	$M 1000		
Annual rate of return		2%	
Traffic calming		Benefits $M/yr	Costs $M/yr
Costs of traffic delays (9.7)			800
Crash costs for new cyclists (9.6 (b))			–
Maintenance costs, 7% of capital (9.7)			245
Annual benefits - cycle facilities			170
Annual benefits - traffic calming			930
Gross annual benefit		55	
Capital cost	$M 3500		
Annual rate of return		2%	

10 Legal issues

10.1 Introduction

This section draws attention to some legal issues affecting cycle safety and suggests changes to present law.

10.2 Cyclist definition

At present a cyclist is included in the definition of a vehicle driver (a motor vehicle driver is also a vehicle driver but has additional responsibilities), and a cycle is included in the definition of a vehicle unless the wheels are smaller than 355 mm diameter (Transport Act 1962, Section 2). These definitions are retained in the Land Transport Bill (1997). The wheel size qualification is presumably intended to allow small children to ride on the footpath but that is not the result. The definitions create several problems.

- Most children's cycles have wheels larger than 355 mm diameter and are defined as vehicles. However, wheels marginally smaller than 355 mm are available and a footpath-legal adult's cycle could be constructed.
- There is no explicit definition of if or when a child may cycle on a footpath, except for newspaper deliveries.
- An adult cyclist is technically unable to ride on a footpath (except for newspaper deliveries) even in situations where it is officially encouraged, such as Wellington's Oriental Bay cycle track.
- A cyclist is still a driver when wheeling his or her cycle, and is technically unable to cross a road as a pedestrian—using a pedestrian crossing for example—or to stop on a footpath.

A better approach is probably to define the rider rather than the cycle. In Denmark the minimum age for solo cycling on the road is 6 years (Ministry of Transport, 1993), but parents rarely allow this in practice. A minimum age seems helpful, but perhaps a graduated minimum would be better, such as:

No limit	for riding on footpaths and cycle tracks away from road crossings.
5 years	for riding on roads while accompanied by an adult, or solo on traffic calmed residential streets.
8 years	for riding solo on all streets.

A maximum age of 10 years could be set for riding on a footpath[14].

[14] Thanks to Jan McKeogh for this suggestion, which comes from German practice.

Recommendation:

- Revise the legal definitions of cycle and cyclist to clarify the position of young cyclists riding on footpaths, define when adult cyclists may ride on the footpath and set minimum ages for cycling in various situations (58).

10.3 Cycle and traffic lanes

At present cycle lanes have no status in New Zealand law, which does not define an exclusive lane for cycles and does not recognise any lane with a width of less than 2.5 m (Traffic Regulations, 1976, Section 2). Prosecuting a driver for misusing a cycle lane might be difficult.

The following lane types are suggested.

Traffic lane—minimum width 2.2 m
The reduced width allows extra-narrow car-only lanes where appropriate: see Figure 6.2.

Advisory cycle lane—minimum width 1.5 m, maximum width 2.5 m
A lane reserved for cycles, with priority for cycles at all times, but which may be used or crossed by motor vehicles when necessary. See 1.7 and 6.8.

Mandatory cycle lane—minimum width 1.5 m, maximum width 2.5 m
A lane exclusively for cyclists. Use by motor vehicles is permitted only in emergency, or to gain access to a private entrance. See 1.7 and 6.8.

Bus-cycle lane—minimum widths 4.2 m for buses and cycles in the same direction, or 6.2 m for buses in one direction and cycles in both directions.
A bus lane where cycle use is permitted. See 6.10.

Cycle track.
An exclusive cycle route, either on a road but physically separated from motor traffic, or on an entirely separate route.

Foot-cycle track.
Shared space for pedestrians and cyclists, usually with pedestrian priority.

These last two might be used to extend present cyclist's law to off-road situations.

Recommendation:

- Define in law the concepts of advisory cycle lane, mandatory cycle lane, bus-cycle lane, cycle track, and foot-cycle track (59).

10.4 Requirement to use cycle facilities

It is reasonable to expect cyclists to use cycle facilities where appropriate but greater flexibility is needed. At present cyclists are required to use a cycle track if one is available:

> *When a reasonably adequate cycle track is available every rider of a cycle or moped shall keep to the track as far as is practical.*
> Traffic Regulations (1976), Sn 41(1)

There are several problems with this requirement.

- Cyclists need the opportunity to avoid poor-quality facilities, which may be more dangerous than none. See 5.7.
- It is generally impractical to design cycle facilities for all cyclists because of their very wide range of speed and ability. See 1.4.
- Faster cyclists fear that they will be required to use facilities unsuited to them and tend to object to any cycle provision. Removing this requirement will simplify agreement on facility design.

The Bicycle Association et al (1996) make it clear that cyclists in the UK are not required to use either advisory or mandatory cycle lanes.

A possible revised clause is:

> When a reasonably adequate cycle track *or cycle lane* is available every rider of a cycle ~~or moped~~ shall keep to the track *or lane* as far as is practical, *unless doing so would expose them to greater danger or delay.*

Recommendation:

- Soften the requirement that cyclists use cycle facilities where available (60).

10.5 Cycle tracks

Off-road cycle tracks may also need legal definition, to separate them from cycle lanes. The concept of advisory and mandatory cycle lanes (see 6.3) is inappropriate as the tracks are not alongside a motor road, and a better concept is priorities (Sustrans, 1997):

Cycle track crossing road
  Priority as shown by signs (not necessarily given to road traffic)

Pedestrians crossing cycle track
  Normally cycle priority

Shared cycle-pedestrian space
  Pedestrian priority

Private vehicle access crossing cycle track
  Normally cycle priority

Recommendation:

- Ensure that cycle tracks can be provided on or off road without legal restraint, and with cycle priority where appropriate (61).

10.6 Speed limits

The present permanent speed limits in New Zealand are 50, 70, 80 and 100 km/h (LTSA, 1997), with 30 km/h permitted only as a temporary measure. However, a 30 km/h speed limit is under consideration (LTSA, 1997a). Even lower speeds are used in some residential areas of Europe.

Recommendation:

- Implement the LTSA proposal permitting 30 km/h speed limits (25).

10.7 Parking

A blanket ban on parking on cycle facilities would be helpful. It would reduce the cost of cycle provision by minimising the need for signs and markings, as well as drawing attention to the needs of cyclists. If necessary, standard cycle lane markings could be in yellow or blue paint.

Recommendation:

- Consider a universal parking ban in cycle lanes (62).

10.8 Liability

New Zealand may have moved too far away from the concept of personal liability: see 11.7. If this is correct then legislation may be needed.

10.9 Cyclist's rights

The current transport debate has highlighted the need to develop rights for all road users (MoT, 1997). Areas to be considered in developing cyclist's rights include the following.

- A general right of access by a reasonably direct route, and by a the flattest reasonably available route.
- Greater vehicle-vehicle clearances than are necessary for four wheel vehicles, for cycle stability at low cycle speeds and/or high motor vehicle speeds.
- A general right to use the centre of a traffic lane when reasonably necessary.

- Protection against risks imposed by others.
- A general right for cyclists below a given age (say 10 years) to use footpaths.
- A restricted right to use footpaths where authorised—for example on a steep rising gradient—where cyclists would delay motor traffic but impose very little risk on pedestrians.

Recommendation:

- Define the rights and responsibilities of all road users (4).

11 Towards a new vision: road danger reduction

11.1 Introduction

In this section several threads are drawn together to suggest that road safety is failing for cyclists, and perhaps also for pedestrians. Cyclists are the canaries in the coal mine of road safety: if the roads are dangerous for these unprotected users they are dangerous for all, however well protected motorised road users may be while strapped into their vehicles.

Cyclists in New Zealand face fatal injury risks some seven times greater than in the Netherlands (see 9.5), and ten times greater for children under ten. However, the dramatic fall in the risks faced by child pedestrians in Denmark, an 84% reduction between 1967 and 1987 (Roberts, 1994), shows that change is possible.

There are equity issues to be considered here. Is it reasonable to allow motorised road users to externalise their costs (time savings) by transferring risk to others, or to design roads so as to erect unnecessary barriers to legal vehicles?

A new direction is needed, based on a new vision, to achieve the quantum changes of best international practice.

11.2 Cycle helmets and conspicuity

Apart from education of children, most effort on cycle safety goes into encouraging cyclists to wear helmets (a legal requirement) and to be conspicuous. There are reasons to doubt the value of both policies, especially when used as a substitute for more positive action.

- The New Zealand standard for cycle helmets (Standards NZ, 1996) specifies a test based on a vertical fall of 1.5 m, giving an impact speed of 19.5 km/h. Helmets made to this standard give good protection if a not-too-tall cyclist falls off, but are little use in a collision with a motor vehicle. The British Standard (BSI, 1989) specifies only a 1.0 m drop (16 km/h), but is specific that:

  > *The requirements of this standard are intended for helmets that give protection in the kind of accident in which the rider falls onto the road without other vehicles being involved.*

- A number of papers, such as Robinson (1996) and Hillman (1993) give grounds for doubting the claimed benefits of helmet wearing.
- Dutch and Danish cycling authorities place little emphasis on either helmet wearing or conspicuity (Wood, 1997 and photographs in CROW, 1993 and Ministry of Transport, 1994 and 1993b)[15]. Cyclists in both countries face much lower risks than faced by New Zealand cyclists.
- Conspicuity as a contributory factor is over-stated in New Zealand (see 4.20) but is still insufficient to provide an important explanation of cycle crashes.

Conspicuity and helmet wearing are useful measures but are unhelpful as the dominant focus of cycle safety. Hillman (1993) says:

> *It could be argued that it is unjust to shift too much responsibility for the safety of cyclists on to the cyclists themselves because they are among the most vulnerable of road users and unable to markedly reduce the risk to themselves of being involved in a road accident ...other than by cycling less or giving up cycling altogether.*

This situation is apparently accepted in the New Zealand Road Code (LTSA, 1997, p 23.0):

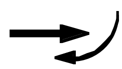
- *Motorists usually travel faster than cyclists and may have less time to take account of hazards.*
- *Motorists may not always see cyclists especially at night or in wet weather.*

What the cyclist is expected to do—other than buying a car—is not explained.

11.3 Perception

Cambridge et al (1991) report a survey where 43% of cyclists involved in crashes with a car stated that they were *not seen in time* by a driver. See 4.18. This problem is certainly not unique to cyclists and the LTSA (1990) says that phrases such as *I just didn't see him* are heard much too often. However, cyclists may be a special problem, illustrated by two recent experiences of mine:

- While cycling I was hit by an initially stationary car turning right (movement code JA, cycle key vehicle), in daylight, when I had right of way and had been in full view of the driver for over 100 m. I thought I had established eye contact but she said she did not see me until she heard me shout, at a distance of perhaps 3–5 m.



- While driving I failed to see a motorcyclist in the same situation (JA, cycle key vehicle) and avoided a crash by good luck.

In both cases the cycle was obvious but not seen by the driver, with no mitigating circumstances such as

[15] However, the last reference mentions encouraging children to wear helmets.

multiple traffic movements. Two reasons seem possible.

- A small object such as a cyclist might be hidden behind a car's windscreen or door pillars. Neither is plausible for the near-right angle cases described above, but roundabout visibility diagrams in Allott and Lomax (1993) suggest that the windscreen pillar might be in the way on some roundabout approaches.
- Drivers may tend not to look for anything smaller than a car. *Perceptually invisible* was the phrase used by an unsurprised psychologist friend.

Evidence for this second hypothesis is strong.

- Brüde & Larsson (1996) say that:

  > *There are indications that* [on roundabouts] *car drivers during the entering phase where they must give way to both cars and cycles tend to look out mainly for cars and thereby miss the circulating cyclist. As an explanation it has been suggested that this could be an example of a general principle that road users more or less unconsciously look out for the road users who represent a danger to themselves and in a sense the cyclist is not directly dangerous to the car driver.*

- A driver who is receiving too much information and failing to process it adequately will not initially recognise the problem (Austroads, 1993a, figure A.2), and will believe that he or she is performing better than is the case.
- Reason (1974, pp 140–1) gives six strategies for information overload:.

  Omission
  : *Where there is an excess of incoming signals, we simply ignore some of them.*

  Error
  : *Processing the information incorrectly and not making the necessary output adjustments.*

  Queuing
  : *Delaying responses at peak load periods and then catching up during the lulls.*

  Filtering
  : *The systematic omission of certain categories of information according to some kind of priority (ignoring signals in the periphery for example).* (See Figure 11.1)

  Approximation
  : *An output mechanism whereby the less precise or accurate response is given because there is no time for precision.*

  Escape
  : *Leaving a situation entirely, or taking other steps that effectively cut off the flow of information —like closing one's eyes and praying.*

  Reason gives the most common strategies as omission and filtering, and either seem reasonable explanations for failure to see an object smaller, slower and closer to the kerb than expected. Allnutt (1984) points out that such strategies are essential because we cannot possibly process all information in detail.

- The Institution of Civil Engineers (1996) says that *drivers do not consider the safety of other road users particularly pedestrians and cyclists.*
- A compound search is appreciably more difficult (Coren et al, 1994). At a road junction the search is for a vehicle **or** pedestrian **or** cyclist, **and** with a conflicting movement **and** with the right speed to conflict. Such a search would be much easier with pedestrians and cyclists omitted, which is what is to be expected if the civil engineers (previous bullet) are correct.
- Hass-Klau et al (1992) give a diagram showing how a driver's (or cyclist's) effective visual field shrinks with increasing speed, and the LTSA (1990) make a similar point. See Figure 11.1.

Cyclists too easily become invisible because drivers are unable to process all the information they receive. The problem is exacerbated by high motor vehicle speeds (Figure 11.1) and low cycle numbers (Figure 4.1). Cyclists will be prone to the same effects but have much greater incentives to overcome them and are generally less exposed to error because of lower speed. And perhaps the absence of windscreen pillars.

Problems of perception are even worse for children. New Zealand is particularly bad in children's road safety, for both pedestrians (Roberts, 1994) and cyclists (see 9.5).

Sandels (1975) draws the following conclusions from a study of child cycle and pedestrian crashes in Stockholm in the late 1960s.

- Children are assumed to have attained a high degree of traffic ability but their real ability is *extremely illusory.*
- The 4 year olds in the study showed very poor traffic behaviour, the 5 year olds were almost as bad and even 6 and 7 year olds were *very uncertain pedestrians.*
- Children who appear to have looked around for approaching vehicles, but who have not in fact done so, may walk out into traffic.

- Where restricted vision was a factor well over half of the obstructions were parked cars (presumably this is now a bigger problem).

Some difficulties particularly affect children.

- Junctions are a greater problem than road links. Children often prefer to cross the street on a straight stretch some distance from the junction (Leden, 1993).
- Drivers judge distance by apparent height and confuse nearby children with more distant adults (Hamer, 1993). Rate of increase in apparent size (optic flow) is only effective in the last second or so before a collision at 50 km/h: too late. A driver sitting 1.8 m above the road sees changes in vertical angle and is less likely to be deceived than a driver 1 m above the road, making this a problem for drivers of cars (and especially sports cars) rather than trucks.
- A relatively quiet street with parked cars is particularly dangerous (Tolley, 1989, Roberts, 1994).

Most of this is derived from work on children as pedestrians rather than cyclists but the skills needed are similar. It seems reasonable to assume that *very uncertain pedestrians* will have similar failings when on wheels.

Elliot (1994) says that the higher the speed the more drivers put the onus on the pedestrian or cyclist to avoid a crash: the attitude of drivers at marked pedestrian crossings is *astoundingly ruthless.* Huxford (1997) says that German drivers are presumed to allow for errors by vulnerable road users, which seems a more fruitful approach.

Recommendations:

- Make drivers more aware of their psychological limitations (18).
- Make drivers more aware of the special limitations of children and more responsible for their safety (19).

11.4 Risk compensation

It seems that people adapt to changes in their perceived level of risk by being more or less careful: risk compensation. If they also fail to allow for the risks that they impose on others, then policies which encourage risk compensation will tend to disadvantage walking and cycling.

Risk compensation has been observed on the roads for at least 90 years. Adams (1995) quotes a letter to The Times (UK) for 13 July 1908 from a Colonel Verner.

> *Before any of your readers may be induced to cut their hedges as suggested by the secretary of the Motor Union they may like to know my experience of having done so. Four years ago I cut down the hedges... to a height of* [1.2 m and for 30 m] *back from the dangerous crossing in this hamlet. The results were twofold: the following summer my garden was smothered with dust caused by fast-moving cars, and the average speed of passing cars was considerably increased. This was bad enough, but when the culprits secured by the police pleaded that "it was perfectly safe to go fast" because "they could see well at the corner", I realized that I had made a mistake. Since then I have let my hedges grow* [to 3 m] *high, by which means the garden is sheltered to some degree from the dust and the speed of many passing cars sensibly diminished. For it is perfectly plain that there are many motorists who can only be induced to go at a reasonable speed at crossroads by consideration of their own personal safety.*

Risk compensation fits with common experience: we tend to take less care if conditions seem safe and extra care if danger is obvious. Rumar et al (1976) studied this effect by observing cars taking an icy bend in

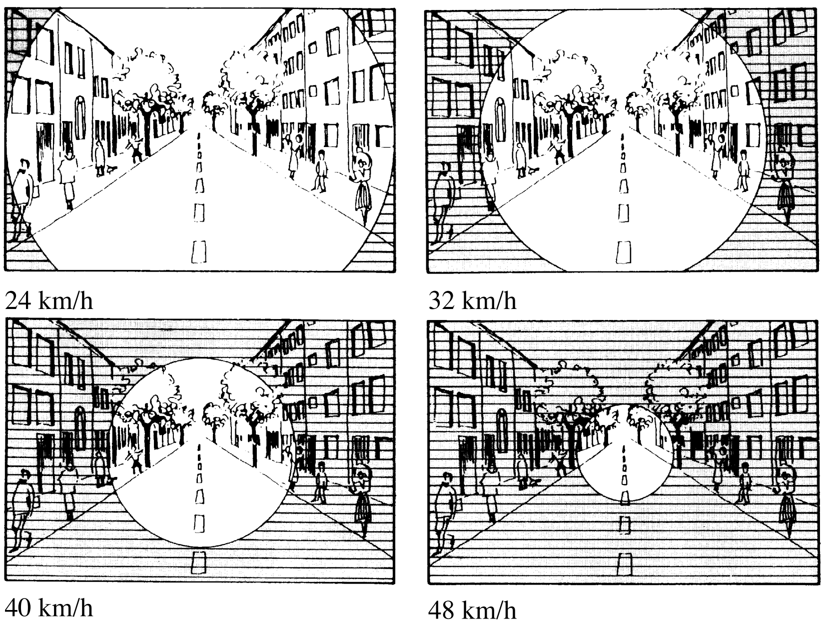


Figure 11.1 Variation of driver's field of vision with vehicle speed

From Hass-Klau et al (1992)

Sweden. The 97.5th percentile speeds were 57 km/h for cars on normal tyres and 63 km/h for studded tyres, a 22% increase in radial acceleration. Cars with studded tyres were faster at even the 25th percentile (about 12 % greater radial acceleration), showing that most drivers were applying some risk compensation: consuming safety benefits to gain time savings.

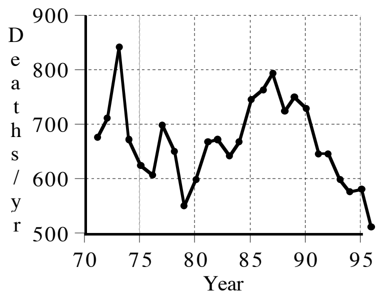
In New Zealand there is currently about 1 road fatality for every 60 million motor vehicle kilometres. In this distance the number of potential incidents is vast—every vehicle, pedestrian, bend or junction passed—so the behavioural change needed to account for risk compensation is very small: imperceptible in many conditions.

There is substantial evidence that risk compensation is important.

- Car seat belts have never achieved the benefits originally claimed. Conybeare (1980) found that Australian seat belt legislation lead to a less-than-expected decline in occupant fatalities and a significant increase in non-occupant fatalities. In the UK an editorial in The Lancet (1986) noted the shortfall of actual lives saved and *the unexplained and worrying increase in the deaths of other road users.*
- Motorists who had been seen driving without using seat belts were observed under experimental conditions (they were told that the study was of seat belt comfort). The researchers concluded that *Seat belt wearing leads to higher speed, more irregular maintenance of speed and later braking* (Janssen, 1989).
- A UK study found that more powerful cars had more than twice the fatality rate of standard cars (occupants and non-occupants), despite their tending to have better safety features (Hamer, 1993).
- Studies in the USA have concluded that driver risk-taking increases with increasing car mass. (Evans and Wasielewski, 1983).
- A study of cycle crashes in Copenhagen showed that the proportion of cyclists riding without lights at night was higher than the proportion without lights who were involved in crashes (Davis, 1993, pp 151–2). This suggests that cyclists without lights were *less* likely to be involved in a crash.

Now air bags and ABS brakes are failing to meet the predictions of their proponents and may be a further threat to vulnerable road users.

Risk compensation compromises or even reverses the value of many safety improvements, so if these road safety measures are ineffective the current decline in New Zealand road deaths and injuries needs explanation. Deaths from all New Zealand road crashes were 514 in 1996 (LTSA data), after



peaking in 1973 (843 deaths, 164% of 1996) and again in 1987 (795 deaths, 155%). Explanations consistent with risk compensation include the following.

- Fewer drunk drivers. The annual number of positive breath- or blood-tests declined by 40% from 1987 to 1993 (LTSA, 1994). The period includes two reductions in permitted alcohol levels, one general and one for the high-risk age group.
- Demographic changes. The total number of high-risk 15–19 year olds was 14% greater in 1986 than in 1996 (Statistics NZ, 1987 and 1997).
- Speed cameras. The Public Health Commission (1994) report a 30% reduction in motor vehicle casualties with the introduction of speed cameras in Victoria.
- Improved medical response to crashes, such as rescue helicopters, leading to fewer deaths from a given level of injury. This will increase injuries at the ‘expense’ of deaths, but the increase will tend to be hidden in the larger numbers and greater uncertainties of non-fatal injuries.
- Increased congestion. This may well increase the total number of crashes but will reduce fatal and serious injury numbers because of lower speeds.
- Other factors. The Royal Commission on Environmental Pollution (1994, figure 4.3) show a downward trend in unprotected road user (child pedestrian) death rates from 1968 to 1990, for England and Wales, Denmark, Sweden, the USA and New Zealand (which had the lowest rate of fall). The common trend suggests some international factor, which could be as simple as increasing vehicle numbers (West-Oram, 1991).

Risk compensation goes to the heart of human behaviour. Do we respond best to encouragement to do better, to fear of failure or penalty, or to some mixture of the two? The dilemma is explicit in the *Four Es* of road safety policy, which cover both options: Encouragement, Education, Enforcement and Engineering. It even extends to the nature of risk. Adams (1995) draws attention to a Royal Society (1992) report saying that:

> *The view that a separation can be maintained between 'objective' risk and 'subjective' or perceived risk has come under increasing attack, to the extend that it is no longer a mainstream position.*

The process of risk estimation and reaction on the roads is perhaps most obvious when walking on a crowded footpath. All participants assess the intentions of others and respond to their actions and the threat that they represent. The number of potential collisions is very large but they are usually avoided. The same process happens on the road but with important differences: signalling intentions to others needs a more formalised system, the consequences of failure are more serious, we do it less well because of information processing limitations and the balance of risk is much less equal. A cyclist and a truck driver impose equal risks on one another, but only when both are walking on the footpath.

11.5 Risk compensation and the four Es

If risk compensation is important there are consequences for the 'Four Es'.

Encouragement
: Encouragement seems effective in long term changes such as the slowly declining acceptability of drunk driving. Perhaps we can now do the same for speeding[16].

Education
: It is possible that education teaches skills that encourage risk compensation. Davis (1993) quotes Winston Churchill, in opposing driving tests, as referring to *undue proficiency leading to excessive adventure.* The value of education may be very limited. Roberts (1994, p 10) comments that none of the child pedestrian safety programmes used in New Zealand have ever been shown to reduce injury rates, and that, *there is also no evidence to suggest that driver education is likely to be an effective prevention strategy.* Education is discussed further in 11.7.

Enforcement
: Tolley (1990) points out that enforcement of speed limits is an important exception to the general rule of risk compensation, *which may be why enforcement is so unpopular.* As an exception it becomes a more valuable measure in a policy environment that recognises the importance of risk compensation.

Engineering
: Engineering may encourage or discourage risk compensation, as discussed below.

11.6 Road danger reduction

Road safety engineering has concentrated on measures to make things as easy as possible for motorised road users, on the assumption that this will reduce crash rates. Typical measures are road widening, curve easing and longer sight lines. If a risk compensation approach is taken, it can be seen that all these measures are likely to lead to higher speeds and will tend to be self-defeating. Other policies might be just as effective: maximum lane widths, guard rails, reduced kerb radii and sight line limits. They would certainly be much cheaper, releasing funds for more effective measures such as enforcement.

In the UK several local authorities have joined a group set up to approach risk compensation positively and achieve a real reduction in risk: the Road Danger Reduction Forum (Davis, c1996). The Forum's showpiece is York, which has officially taken a danger reduction approach since 1989. There has been impressive progress since, although little of the approach taken seems novel in a Dutch or German context. There has been extensive traffic calming and provision for pedestrians and cyclists. Traffic has only increased at a quarter of the national average rate, while crash deaths and injuries have fallen dramatically. See Table 11.1.

Table 11.1: Changes in casualty rates, York and UK

1994 compared with 1981–85 average
(from Davis, c1996)
(1981–85 is the UK government baseline)

	York %	UK %
All casualties	- 46.5	- 2.0
Pedestrians	- 42.0	- 21.0
Cyclists	- 32.5	- 12.5
Car drivers	+ 4.5	+ 50.5
Car passengers	- 17.5	+ 16.5

The principle of road danger reduction is that responsibility for road safety is placed on those who have most power to control it: drivers. These measures are suggested by The Institution of Civil Engineers (1996).

- Traffic calming. Suggested speeds are <32 km/h generally and <16–24 km/h in specific locations.

[16] These points were made in The Dominion for 14 April 1998, reporting comments on the Easter 'Road Toll' by Police Assistant Commissioner Phil Wright

- Traffic lights at junctions in preference to roundabouts or uncontrolled crossings.
- School crossing patrols.
- Speed reduction outside schools.

Tight et al (1998) show that a road danger reduction approach can be used with the more traditional crash reduction approach, and the results are more compatible with the public perception of road safety. Using traditional thinking, roads which are widely perceived as dangerous may not be officially recognised because road users apply risk compensation and there are few crashes. Tight et al (1998) also comment that the UK National Audit Office have compared UK road safety policy unfavourably with industrial safety policy, *where the onus of responsibility and liability is clearly located with those who produce danger.*

Recommendation:

- Adopt a 'Road danger reduction' approach to road safety (3).

11.7 Social attitudes and education

Anecdotal evidence suggests that in New Zealand social attitudes towards vehicle use are particularly bad. The major dangers faced by cyclists and pedestrians are largely inflicted by others and it is here that social attitudes become crucial.

In the UK The Institution of Civil Engineers (1996) has gone well beyond a purely engineering approach.

Education
> *To make individuals aware of how their actions affect the safety of others and how each individual must take responsibility*

Engineering
> *To reduce the risk of crashes, and to prevent injuries should a crash occur*

Enforcement
> *To ensure traffic regulations provide effective protection for all road users*

Encouragement
> *Encouraging people to travel less, especially by car.*

The Civil Engineers' comment is that road danger must be adopted as an issue of social responsibility if best practice is to be achieved. The UK Royal Commission on Environmental Pollution (1994, section 4.38) suggest that the same attitude could usefully be applied in New Zealand:

> *Denmark and Sweden have sought to reduce deaths amongst child pedestrians through traffic restraint policies which involve reducing speed limits in urban areas and designating zones in which pedestrians have priority. In contrast, the UK, USA and* ***New Zealand*** *have placed the emphasis on educating children in road safety. A comparison of trends in child pedestrian mortality over the last 20 years suggests that traffic restraint policies have been a more effective approach.* (emphasis added)

If there is no evidence that education is effective (see 11.5), I hesitate to suggest solutions relying on education, but the need is clear: the doubts are about whether it can be delivered effectively.

Motor vehicle drivers generally need education in safe road sharing with cyclists. McClintock (1992, p 89) refers to UK research showing a need for driver training on the needs of vulnerable users.

> *Making drivers do some bicycle riding as part of their driver training certainly... has its attractions as a way of inculcating greater understanding... A reasonable co-existence of drivers and cyclists is also probably helped by a public recognition of the importance of cycling, still so lacking in many countries.*

The following areas need attention in New Zealand.

- Bicycles are vehicles with rights on the road. The Road Code should show situations where a car gives way to a bicycle.
- Cycle speeds are very variable and other road users need to be aware that their assumptions about speed need checking.
- Cyclists need space to wobble—especially at low speeds—and are badly affected by the slipstream of high speed vehicles. A minimum clearance of 1.5 m has been suggested (Cycle Aware, 1998). Overseas practice quoted by Cycle Aware is: France 1.5 m, Alberta (Canada) one lane width, Boulder (USA) 0.9 m. The sketch is from HMSO (1996), who do not recommend a figure.
- Promoting the need for enforcement of speed limits.

In New Zealand education of cyclists has traditionally been along the lines described by the Road Danger Reduction Forum (1997).

> *The 'hidden curriculum' of road safety education for pedestrians and cyclists has been that:*
>
> - *They are the problem, not the ever-increasing level of road danger.*
> - *The increase in road danger is a 'fact of life'.*

Education proposed by the forum includes *practical* training in road safety.

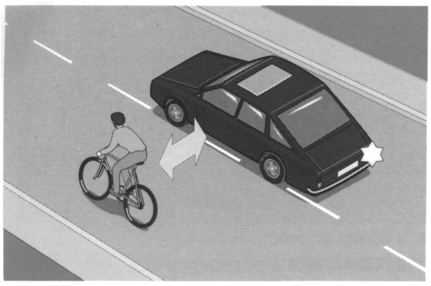
- *Pedestrian and cycle training programmes designed to encourage and promote walking and cycling.*

- *Programmes aimed at the empowerment of children to show that they have choices and can make a difference.*
- *Demonstrating the links between transport and other environmental issues in ways that encourage children to see how they can contribute in a positive way.*
- *Methods which involve the whole school, including teachers and parents, in the process of change.*

Franklin (1997) gives excellent advice on cycling skills, in a UK government publication that could usefully be adapted for use in New Zealand. He recommends two basic road positions for cyclists.

> ***Primary position:***
> *In the centre of the leftmost moving traffic lane for the direction in which you wish to travel. Here you will be in the zone of maximum surveillance of both following drivers and those who might cross your path.*
>
> ***Secondary position:***
> *About 1 metre to the left of the moving traffic lane if the road is wide, but not closer than 0.5 m to the edge of any road. Riding closer to the edge would leave you with no room for manoeuvre in the event of an emergency, while increasing the need to make unpredictable movements which could lead to a crash.*

In a chapter headed *The more difficult manoeuvres,* Franklin includes right turns in multi-lane roads, roundabouts (16 pages!), merges and diverges. In most cases he recommends the primary position. In contrast, the Bike Code (LTSA, 1996a, p 26) says that cyclists should ride 1 m out from the kerb or parked cars, but allowing room for car doors being opened. The Bike Code contains two photographs of a cyclist riding in a straight line. Both show a child at least a metre further to the left than recommended by Franklin, one of them badly exposed if a car door were to open. Both scenes are on a wide road with plenty of room to take a safer position.



HMSO (1996)

Recommendations:

- Amend the Road Code to show cases where drivers give way to cyclists, and give specific recommendations to drivers on clearances for overtaking cyclists (20).
- Introduce practical road safety training for school children (21).
- Consider producing a New Zealand cycling skills book similar to Franklin (1997) (22).
- Incorporate the concept of primary and secondary riding positions into New Zealand cycling education (23).
- Locate or undertake research on social attitudes to vehicle use as a baseline for future surveys (70).

11.8 Effects of New Zealand legislation

It is clear that in the USA and Canada, driver's attitudes to pedestrians—and presumably also cyclists—are very different from those in New Zealand (Personal observation while visiting Oregon and Vancouver in 1994, and Maine and New Brunswick in 1997). Adams (1995) comments that driving in the USA feels much safer than driving in the UK, but the risks are in fact much the same. Fatality figures (LTSA, 1994) are given in Table 11.2.

Table 11.2: Road death rates for New Zealand, the UK and USA

	per 100 000 vehicles	per 100 000 population
USA	2.0	15.4
UK	1.5	7.6
NZ	2.7	17.0

There are two obvious differences in the legislative background.

- In New Zealand we have attempted to specify which road users do and do not have right of way in all circumstances, with the result that intersections are covered in 36 pages in LTSA (1997b), but in 7 pages in State of Maine (1997) and 5 pages in both HMSO (1996) and the Department of Transport (1996) in Western Australia. In HMSO the *only* give-way rule for an uncontrolled intersection (no traffic signals, stop or give way signs) is for turning drivers to give way to pedestrians crossing the road the driver is entering.
- In New Zealand we have 'no blame' legislation. In contrast, North American drivers are very much aware of the risks of being blamed for a crash, and seem to drive accordingly. The UK possibly forms an intermediate case.

The problem here is that by trying to specify who gives way in all cases, we have specified who does *not* give way, so drivers who believe they have the right of way tend to drive as if no other road users are present. Ewing (1993, p 17), writing in an aircraft safety context, refers to the danger of *hazardous thoughts,* such as avoiding responsibility (*that's the other aircraft's worry, not mine*), or acting in a 'macho' way. Drivers prone to hazardous thoughts (most of us?) tend to enter junctions faster than they would in many other countries. Add to this their tendency to discount risks to others, and in New Zealand we may have created a recipe for disaster for cyclists.

- Give way rules at junctions are complex and often poorly understood.
  (Note the movement coding description in 2.3: *Cyclist failed to give way when deemed turning, to non-turning or deemed non-turning traffic* and the 36 pages of give way rules in the Road Code).
- Drivers tend to discount risk to others.
- Drivers who have—or believe they have—right of way tend to ignore other road users and travel at higher speeds.
- Drivers tend not to see other vehicles, and cyclists in particular. This failure is exacerbated by higher speeds.
- ACC legislation has introduced a no-blame framework, reinforcing the tendency to discount risk to others.

These factors suggest that we shall not achieve best international practice in cycle safety—and urban transport sustainability—until we have developed ways of offsetting our legislative peculiarities and the attitudes they encourage. Lower speed limits, improved enforcement and traffic calming will be part of the solution but it seems only too likely that we shall need something more. What that might be is unclear, but it would need to include greater responsibility placed on drivers in some way.

The attitudes encouraged by the New Zealand Give Way rules are particularly inappropriate in traffic calmed areas, and when New Zealand has some reasonably large areas with 30 km/h speed limits a trial of the UK system (HMSO, 1996) might be worth while.

Recommendation:

- Investigate the possibility that New Zealand legislation is indirectly promoting unsafe road conditions through detailed give-way rules and no-blame legislation (6).

11.9 Vision and targets

York and other cities are showing the English-speaking world another way forward, and they are backed by many European examples to show that the economics of traffic restraint are sound (Kenworthy et al, 1997). York is not a special case because of tourism, geography or layout. But the results achieved in York need a change in thinking at least as much as changes in road layout, and for this a new vision is needed.

The vision proposed by The Institution of Civil Engineers (1996) is *To make travel by all modes as safe as public transport.* (Public transport is currently the safest transport mode)

The Road Danger Reduction Forum's vision (1997a) is of,

- *All road users being able to travel where they choose with a minimum of threat from other road users*
- *All road users taking full responsibility for the effects their transport choices have on others*
- *An environmentally sustainable transport system which provides equity and accessibility for all road users, permitting no disadvantage for those who choose not to own a car.*

The Royal Commission on Environmental Pollution (1994) recommend two targets which seem relevant here. I have adapted both as recommendations (Recommendations 1 and 2 in Appendix A):

> ***Target C 2***
> *To increase cycle use to 10% of all urban journeys by 2005 compared to 2.5% now, and seek further increases thereafter on the basis of targets to be set by the government.*
>
> ***Target C 3***
> *To reduce cyclist deaths from* [41 per billion] *km to not more than* [20 per billion] *km cycled by 2000.*

The reason for the Royal Commission using targets related to distance travelled is,

> *...in order to emphasise that the aim is a genuine improvement in the safety of cycling and to remove the possibility that a target for reducing casualties could be met by policies which merely led to a further fall in the already low level of cycling...* (p 54)

Recommendation:

- Develop a new vision for road safety for all road users, based on the proposals by The Institution of Civil Engineers (1996) and the Road Danger Reduction Forum (1997) (7).

12 Summary and recommendations

12.1 Introduction

This section summarises the main conclusions reached. Recommendations made in the text are outlined in 12.4 and given in full in Appendix A.

12.2 Policy implications

Good quality cycle provision offers real policy options. Cycling fits well with policies supportive of urban containment, public transport, pedestrianisation, traffic restraint, lower transport costs, improved economic and environmental sustainability, improved public health and improved road safety.

Significant reductions in motor vehicle use are achievable, especially in the most polluting short trips. Many trips presently made by car are well within cycling range: the average length of an urban car trip is only 5 km. Some people are willing to cycle more than twice this distance, and in congested traffic many people find cycling the fastest means of travel. Nationwide, 20% or more of commuters cycling to work is a practical option: 16% by 2016 is the target suggested here. The best UK workplaces have already achieved 25%, and the best Dutch cities 60%. In the main centres even greater numbers could cycle to the bus or train. Other cycle use is less well understood but seems to be reasonably proportional to cycle commuter numbers. Greatly increased numbers cycling to and from school or shops is practical, increasing sustainability and widening transport choice.

The overall fatality rate is at present around sixty per billion kilometres cycled, which is high in international terms. The average cost of reportable crashes is around 45 cents/km: some five times the average for car use. With supportive policies this could be reduced sixfold to around 7 cents/km. Non-reportable crashes (those not involving a motor vehicle) presently cost as much as reportable crashes but here too, the risk is reducible, probably substantially. Taking a holistic approach and considering the benefits of cyclist's health, reduced congestion and reduced pollution, makes cycle use already safer and more economically attractive than car use, for some journeys.

The average costs conceal wide variations. Cycling in New Zealand is already twice as safe as driving for the high risk 15–20 years age group. It may be safer for most adults younger than 60 if the wider benefits are considered. At the other end of the scale, the cost of young children's cycling risk may be comparable with the cost of taking a taxi.

Three broad methods are available to reduce cyclist's risk: they are best applied together.

- Integrated cycle facilities on busier streets or on equally direct alternative routes. Use semi-segregated facilities where actual traffic speeds are higher than 30–60 km/h, depending on traffic density.
- Traffic calmed residential streets and selected CBD and shopping streets.
- Encourage wider use of cyclingencouraged, which will itself reduce cyclist's risk. The effect is strongest in centres where cycling is at present least common and least safe. It is due simply to drivers becoming used to looking out for cyclists.

Costs for this approach—including the cost of delays to motor traffic—are substantially lower than the cost of providing for additional urban traffic in motor vehicles.

Safe cycle touring could open New Zealand to a lucrative new tourist market.

Achieving best international practice will need road space dedicated to cycles. Most of it will have to be space presently taken by motor vehicles, for either driving or parking. Major benefits are available from this approach and costs are lower than might be expected.

- Transferring space to cycles increases the people-carrying capacity of urban roads by at least 60%, and sometimes by over 300%. Parking space converted to cycle use increases parking capacity—in people-carrying terms—sevenfold.
- Making space for cycles—*limiting the opportunities for driver misbehaviour* in the Dutch phrase —increases safety for all road users.
- Motor vehicles need less space when they travel more slowly.

Achieving the benefits of safer cycling will need a major rethink of the way we prioritise and design for urban transport. However, the pioneering work has been done, the methods are known, the costs are reasonable. The benefits of encouraging cycle use and related policy choices are very large. We can no longer afford to ignore them.

A final recommendation is to make a similar study for pedestrians, who face the same fundamental problems as cyclists: vulnerability, and perceptual invisibility to both drivers and policy makers.

12.3 Key findings

- Cyclist's risk is higher in New Zealand than in many OECD countries. It is about seven times greater than in the Netherlands. If helmet wearing and conspicuity programmes are effective in New Zealand they are concealing an even greater disparity in the safety of the cycling environment.

- Greater cycle use will itself reduce cycling risk.
- The risk of a cyclist being hit from behind—the worst crash type for New Zealand fatalities—is lower than in the 1970s but is still very high.
- The quality of crash recording is poor, with reporting rates low in international terms. Crashes due to crowding by a motor vehicle and road surface problems are heavily under-reported, and cycle conspicuity problems are over-reported.
- Cycle use is declining at much the same rate as cycle casualties. Cycle safety is not improving significantly and may well be getting worse.
- Road and junction improvements made on safety grounds are frequently made less safe for cyclists.
- Motor vehicle speed is crucial in controlling risk to unprotected road users.
- Special cycle facilities are seldom available, and where provided are often of poor quality. A poor-quality facility may be more dangerous than none.
- Good quality cycle-friendly road designs are available, particularly from Europe, and need only minor adaptation for use in New Zealand.
- Traffic calming policies are supportive of local cycling but need to be designed with cycle safety in mind.
- Commuter cycle numbers are a reasonably good proxy for total cycle numbers.

12.4 Key recommendations

See Appendix A for a full list of the recommendations made in the text.

- Develop a new vision of road safety, including rights and responsibilities for all road users.
- Adopt a national cycling strategy.
- Set targets for reduced death and injury rates by mode of travel. A suggested target for cyclists is no more than 20 fatalities per billion kilometres cycled by 2008.
- Set a target of doubling cycle numbers within 6 years, then doubling again within 10 years, to reach a national figure of 16 % of commuters on cycles by the 2016 census.
- Fully integrate cycle planning into road planning and design methodologies.
- Ensure that all future road designs are either cycle-friendly or easily by-passed by cycles.
- Place much more emphasis on reducing motor vehicle speeds, and requiring drivers to make allowances for children's behaviour.
- Develop high quality standards for cycle facilities.
- Develop a framework for evaluation of cycle facilities.
- Update transport law applying to cyclists.
- Adopt a road danger reduction approach to road safety.
- Introduce 30 km/h speed limits in residential areas.
- Emphasise safe cycling routes to school and public transport.
- Limit the use of cycle lanes to appropriate situations, using unsegregated roads for low speeds and low traffic densities, and segregated facilities in other cases.

13 References

Adams, J (1995)
Risk. London: UCL Press

Aggernaes, G (1993)
Quality is reflected by the usage. In *Velocity Conference.* Nottingham, UK: Nottingham City Council

Allnutt, M (1982)
Human factors: basic principles. In Hurst, R & Hurst, L (eds), *Pilot Error: the human factors.* New York: Jason Aronson

Armstrong, B (1994)
Cycle casualties at Emergency Department, Christchurch Hospital, 1 September 1991–31 August 1994. Christchurch, NZ: Road Safety Unit, Public Health Service, Healthlink South

Allott & Lomax (1991)
Cyclists and roundabouts: a review of literature. Goldaming, UK: Cyclist's Touring Club

Atkinson, J E & Hurst, P M (1982)
Collisions between cyclists and motorists in New Zealand. Traffic Research Report 27. Wellington: Ministry of Transport

Atkinson, J E & Hurst, P M (1984)
A study of adult bicycle use in Christchurch and Palmerston North. Traffic Research Report 34. Wellington: Ministry of Transport

Austroads (1993)
Guide to traffic engineering practice: part 14, Bicycles. Sydney: Austroads, P O Box K659

Austroads (1993a)
Guide to traffic engineering practice: part 7: Traffic Signals. Sydney: Austroads, P O Box K659

Austroads (1998)
Guide to traffic engineering practice: part 14, Bicycles (2nd ed) Draft for comment. Sydney: Austroads, P O Box K659

Bachels, M (1996)
Developing positive feedback for sustainable transport: learning from car dependence. *Sustainable Energy Forum Conference,* Tauranga

Baier, R (1996)
Present elements of bicycle traffic support in Germany. *Velo Australis.* Perth, WA: Perth City Council

Ballantine, R (1976)
Richard's Bicycle Book. London: Pan Books

Banister, D (1994)
Transport planning in the UK, USA and Europe. E & FN Spon. In Massey University (1998) *32.702 Transport Planning and Policy readings, volume 1.*

Begg, D; Langley, J; & Chalmers, D (1991)
Bicycle road crashes during the fourteenth and fifteenth years of life. *NZ Medical Journal*, 104 (906)

Bracher, T (1992)
Practice: Germany. In McClintock, H (ed) *The bicycle and city traffic, principles and practice.* London: Bellhaven Press

British Medical Association (1992)
Cycling Towards Health and Safety. Oxford: University Press

Brown, EC, (1996)
Churchill Fellowship: Crash analysis—motorcycles, pedestrians, cycles. Wellington: Region 4 Police HQ

Brüde, U & Larsson, J (1996)
The safety of Cyclists at roundabouts: a comparison between Swedish, Danish and Dutch results. Linköping, Sweden: Swedish National Road and Transport Institute

BSI (1989)
BS 6863: Specification for pedal cyclist's helmets London: British Standards Institute

Cairns, S (1995)
Travel for food shopping: the fourth solution, *Traffic Engineering and Control,* 36(7)

Cairns, J; Hass-Klau, C & Goodwin, P (1998)
Traffic impact of highway capacity reductions: assessment of the evidence. London: Landor Publishing

Cambridge, S; Gadd, M; Holland, G; Huntingdon, D; & Macbeth, A, (1991),
Cycle use and collisions in Christchurch. Wellington: Transit NZ

Carlo, D (1998)
Slow down. *Transport Retort* 21 February, London: Transport 2000.

CART (c1994)
What is traffic calming and how does it work? Ashgrove, Queensland: Citizens Against Route Twenty

Centre for Research and Contract Standardisation in Civil Engineering, (1993)
Sign up for the bike, design manual for a cycle-friendly infrastructure. Netherlands

Children's Play Council (1998)
Home zones: reclaiming residential streets. London: Children's Play Council, 8 Wakley St

Christchurch City Council (1996)
Cycle strategy for Christchurch city. Christchurch: City Streets Unit

Clare, P (1996)
Future directions in traffic management and road safety. In *NZ Local Authority Traffic Institute, 48th Annual Conference*

Cleary, J (1992)
Benign modes, the ignored solution. In *Traffic congestion, is there a way out?* Whitelegg, J (ed) Hawes, UK: Leading Edge

Clouston, E (1995)
Tricycle hits road into the future. *The Guardian* (UK) July 4

Conybeare, JAC (1980)
In Noland, RB (1994), Perceived risk and modal choice: risk compensation in transportation systems, *Accident Analysis and Prevention,* 27 (4)

Coren, S; Ward, CM; & Emms, JT (1994)
Sensation and perception, 4th ed, Fort Worth, USA: Harcourt Brace College Publishers

CROW (1993)
See 'Centre for Research and... '
(CROW is the Dutch acronym, prominent on the cover of the English edition)

Cumming, A & Shepherd, R (1996)
Retrofitting bicycle lanes on existing main roads. Christchurch: *Proceedings of the Transit NZ Land Transport Symposium*

Cycle Aware (1998)
Submission on the *Land Transport Bill, 1997.* Wellington

Cyclists's Public Affairs Group (1996)
Memorandum of evidence. London: House of Commons Transport Committee, HC 373

Danish Ministry of Transport (1993a)
See Ministry of Transport (1993a)

Danish Ministry of Transport (1994)
See Ministry of Transport (1994)

Davis, R (1993)
Death on the Streets. Hawes, UK: Leading Edge

Davis, R (c1996)
Is it safe? a guide to road danger reduction. Leeds, UK: Road Danger Reduction Forum, York, UK: RDRF, c/o City of York

Department of the Environment, Transport and the Regions (1997)
Traffic advisory leaflet 5/97—Cycles and lorries. London

Department of Transport (1996)
Drive safe—a handbook for WA drivers. Perth: Traffic Board of Western Australia

Department of Transportation (1994)
Executive summary—the national bicycling and walking study. Washington: US Government Printing Office. Reprinted in Massey University (1998) *32.702 Transport Planning and Policy readings, volume 2.*

Elliot, B (1994) *Children and Road Accidents—an analysis of the problems and some suggested solutions.* Canberra: Federal Office of Road Safety, Department of Transport

Evans, L & Wasielewski, P (1983)
Do drivers of small cars take less risk in everyday driving? Research Publication GMR 4225, Warren, Michigan: GM Research Laboratories. In Adams, J (1995), *Risk.* London: UCL Press

Ewing, RL (1993)
Aviation Medicine and other human factors for pilots. Auckland: David Ling Publishing

Fietsersbond enfp (1997)
Cycling in Dutch Cities—ten excursions in the Netherlands. Utrecht

Forester, J (1994)
Bicycle transportation, a handbook for cycling transportation engineers (2nd ed). Cambridge: MIT Press

Franklin, J (1997)
Cyclecraft—skilled cycling techniques for adults. London: The Stationary Office

Godefrooij, T (1997)
Segregation or integration of cyclists? the Dutch approach. In Tolley R (ed) *The greening of urban transport,* (2nd ed). Chichester, UK: John Wiley

Hamer, M (1993)
Beware oncoming traffic. *New Scientist,* 8 August

Hass-Klau, C; Nold, I; Bocker, G; Crampton, G (1990)
An illustrated guide to traffic calming. London: Friends of the Earth

Hass-Klau, C (1991)
Anglo-German study of Cycle Safety. In McClintock, H (ed)(1992), *The bicycle and city traffic, principles and practice.* London: Bellhaven Press

Hass-Klau, C; Nold, I; Bocker, G; & Crampton, G (1992)
Civilised streets, a guide to traffic calming. Brighton, UK: Environmental & Transport Planning

Hass-Klau, C (1997)
Solving traffic problems in city centres: Nurenberg —a case study. London: Proc Inst Civ Engrs, *Municipal Engineer* 121, June

Heierli, R (1996)
European Lecture: Public transport in Zurich, London: Proc Instn Civ Engrs, *Transport* 117, November

Hillman, M (1993)
The cycle helmet: Friend or foe? *Velocity Conference.* Nottingham, UK: Nottingham City Council

Hillman, M (1997)
The potential of non-motorised transport in promoting health. In Tolley, R (ed) *The greening of urban transport (*2nd ed). Chichester, UK: John Wiley

Homburger, WS, et al (1996)
Fundamentals of Traffic Engineering. Berkeley, California: Institute of Transportation Studies. Reprinted in Massey University (1998) *32.702 Transport Planning and Policy readings, volume 1.*

HMSO (1996)
The highway code. London: Her Majesty's Stationary Office

Hudson, M; Levy, C; Nicholson, J; Macrory, R; & Snelson, P (1982)
Bicycle planning. London: The Architectural Press

Hülsmann, W (1997) Towards the bicycle-friendly town in Germany, in Tolley, R (ed), *The greening of urban transport.* (2nd ed). Chichester, UK: John Wiley

Huxford, R (1997)
AME briefing sheet: Child pedestrian safety in the UK. London: Proc Instn Civ Engrs. *Municipal Engineer* 121, March

Hynson, R (1997)
Cycling is not hazardous. In University of Waikato, *Planning and promoting cycling in urban areas: Symposium proceedings.* 15 October

Jacobsen, H & Siboni, L (1992)
Practice: Odense, Denmark. In McClintock, H (ed)(1992), *The bicycle and city traffic, principles and practice.* London: Bellhaven Press

Janssen, W (1989)
Working paper on results of seat belt study, TNO Institute for Perception. In Davis (1993), *Death on the Streets*. Hawes, UK: Leading Edge

Keall, MD (1995)
Pedestrian exposure to risk of road accident in New Zealand. *Accident Analysis and Prevention,* 27 (5) pp 729–40

Kenworthy, J; Laube, F; Newman, P & Barter, P (1997)
*Indicators of transport efficiency in 37 global ci*ties. Perth: Institute for Science and Technology policy, Murdoch University

Kingston Morrison (1997)
Report on land use and urban design guidelines for support of cycling in the Wellington Region. For Wellington Regional Council

Land Transport Bill (1997)
87-1. Wellington

Leden, L (1993)
Planing for bicycles in Scandinavia. *Velocity Conference.* Nottingham, UK: Nottingham City Council

LTSA (1990)
Drive Plan 3: Searching techniques (video). Wellington: Land Transport Safety Authority

LTSA (1994)
Motor accidents in New Zealand: statistical statement calendar year 1993. Wellington: Land Transport Safety Authority

LTSA (1995)
Safety directions (2nd ed). Wellington: Land Transport Safety Authority

LTSA (1996)
Road safety atlas. Wellington: Land Transport Safety Authority

LTSA (1996a)
The bike code—your guide to safer cycling. Wellington: Land Transport Safety Authority

LTSA (1997)
New Zealand road code. Wellington: Land Transport Safety Authority

LTSA (1997a)
Rule 54 00: Land Transport Safety (Setting of speed limits) (yellow draft). Wellington: Land Transport Safety Authority

McClintock, H (ed)(1992)
The bicycle and city traffic—principles and practice. Bellhaven Press, UK

McDonald, PD (1977)
Changing Gear. Wellington: Friends of the Earth

Maxwell, T (1998)
Bullbar paranoia angers owner. *The Evening Post.* Wellington, May

MoT (1992)
New Zealand household travel survey July 1989–June 1990. Wellington: Ministry of Transport, Traffic Research Report 43

MoT (1993)
A national bicycle strategy for New Zealand. Unpublished discussion paper. Wellington: Ministry of Transport

Ministry of Transport (1993a)
The bicycle in Denmark—present use and future potential. Copenhagen: Ministry of Transport, Road Directorate

Ministry of Transport (1994)
Safety of cyclists in urban areas: Danish experiences. Copenhagen: Ministry of Transport, Road Directorate

MoT (1995)
Land Transport Pricing Study—The cost of roading infrastructure. Wellington: Ministry of Transport

MoT (1996)
Land Transport Pricing Study—Environmental Externalities. Wellington: Ministry of Transport

MoT (1997)
Road reform—the way forward. Wellington: Ministry of Transport

MoT (1997a)
Greenhouse gas emissions from New Zealand transport. Wellington: Beca Carter Hollings & Ferner Ltd, for MoT

MoT (1997b)
Vehicle fleet emissions control strategy: Stage 1—carbon monoxide emissions from petrol vehicles. Wellington: Ministry of Transport

National Roads Board & Urban Transport Council (1985)
Guide to Cycle Facilities. Wellington: National Roads Board

Newman, A (1996)
Local government learns about cycling. *Velo Australis.* Perth, Australia: Perth City Council

Newman, P; Kenworthy, J; & Lyons, T (1990)
Transport energy conservation policies for Australian cities. Perth: Institute of Science and Technology Policy, Murdoch University

Nolan (1995)
Perceived risk and modal choice: risk compensation in transport systems. *Accident Analysis and Prevention,* 27 (4)

O'Flaherty, CA (ed)(1997)
Transport planning and traffic engineering. London: Arnold

OECD (1986)
Road accidents: on-site investigations. Paris: Organisation for Economic Co-operation and Development.
Plowden, S & Hillman, M (1996)
Speed control and transport policy. London: Policy Studies Institute
Public Health Commission (1994)
The Public Health Commission's advice to the Minister of Health, 1993–4. Wellington: Public Health Commission
Räsänen, M & Summala, H (1998)
The safety effect of sight obstacles and road markings at bicycle crossings. *Traffic Engineering & Control* 39 (2)
Reason, J (1974)
Man in motion: the psychology of travel. London:Weidenfeld and Nicolson
Ringer, B (1994)
New Zealand by bike. Vancouver: Douglas & McIntyre
Road Danger Reduction Forum (1997)
Briefing paper 4: road safety education. York, UK: RDRF, c/o City of York
Road Danger Reduction Forum (1997a)
Briefing paper: An introduction to road danger reduction. York, UK: RDRF, c/o City of York
Roberts, I (1994)
The prevention of child pedestrian injuries. Auckland: Injury Prevention Research Centre, University of Auckland
Robinson, B (1996)
Is there any reliable evidence that Australian helmet legislation works? *Velo Australis.* Perth, Australia: Perth City Council
Rose, M (1995)
Success at any cost. *Surveyor*, 23 November
Royal Commission on Environmental Pollution (1994)
Eighteenth report: Transport and the environment. London: HMSO
Royal Commission on Environmental Pollution (1997)
Twentieth report: Transport and the environment—developments since 1994. London: HMSO
Royal Society (1992)
Risk: Analysis, perception and management. London: The Royal Society. In Adams, J, (1995, p 9), *Risk.* London: UCL Press
Rumar, K; Berggrund, P; Jernberg, U; & Ytterbom, U (1976)
Driver reaction to a technical safety measure—studded tyres. *Human Factors* 18 p 443–54. In Adams, J, (1995, p 54), *Risk.* London: UCL Press
Ryle, TJ (1996)
Advanced stop lines for cyclists: the role of central cycle lane approaches and signal timing, TRL 181. London: Transport Research Laboratory
Sammer, G (1993)
General 30 km/h speed limit in the city through roads excepted: an essential component in cycling promotion. *Velocity Conference.* Nottingham, UK: Nottingham City Council
Sandels, S (1975)
Children in Traffic. Revised ed. Edited by James Harley, translated from the Swedish by Hunter Mabon. London: Paul Elek
Schrank, C & van Munchen, J (1994)
The safety of roundabouts in the Netherlands. *Traffic Engineering and Control,* 35 (3), UK
Sharples, R (1995)
A framework for the evaluation of facilities for cyclists. (in two parts) *Traffic Engineering and Control,* 36 (3) & 36 (4), UK
Shayler, M; Fergusson, M; Rowell, A (1993)
Costing the Benefits: the value of cycling. Goldaming, UK: Cyclist's Touring Club
Standards NZ (1996)
AS/NZS 2063: Pedal cycle helmets. Wellington: Standards New Zealand (published jointly with Australian Standards)
State of Maine (1997)
Motorist handbook and study guide. Maine, USA: Department of the Secretary of State
Standing Advisory Committee on Trunk Road Assessment (1994)
Trunk roads and the generation of traffic. London: HMSO
Statistics New Zealand (1992)
1991 census of population and dwellings—final counts. Wellington
Statistics New Zealand (1997)
1996 census of population and dwellings—final counts. Wellington
Sustrans (1997)
The National Cycle Network, guidelines and practical details, Issue 2. Bristol, UK: Sustrans Ltd and Ove Arup and Partners
Swinburn, B (1997)
Injecting health evidence into cycling advocacy. In University of Waikato, *Planning and promoting cycling in urban areas: Symposium proceedings,* 15 October
The Association of Metropolitan Authorities; The Association of County Councils: & the Association of District Councils (1996)
Memorandum of evidence. London: House of Commons Transport Committee, HC 373

The Bicycle Association; Cyclist's Touring Club; & the Institution of Highways and Transportation (1996)
Cycle-friendly Infrastructure—Guidelines for Planning and Design. London: The Bicycle Association

The Institution of Civil Engineers (1996)
A vision for road safety beyond 2000. London

The Lancet (1986)
Editorial, January. In Davis, R (1993) *Death on the Streets.* Hawes, UK: Leading Edge

The World Bank (1996)
Sustainable Transport. Washington

Tight, M; Page, M; Wolinski, A; & Dixey, R (1998)
Casualty reduction or danger reduction: conflicting approaches or means to achieve the same ends?, *Transport Policy* (5) pp 185–92

Tolley, R (1989)
Calming Traffic in Residential Areas. Dyfed, UK: Brefi Press

Tolley R (ed) (1990)
The greening of urban transport. Chichester, UK: John Wiley

Tolley, R & Turton, B, (1995)
Transport systems, policy and planning. Harlow, UK: Longman

Topp, HH (1990)
Traffic safety, usability and streetscape effects of new design principles for major urban roads, *Transportation,* 16, pp 297–310

Transit NZ (1994)
Manual of traffic signs and markings, Vol 2: Markings. Wellington: Transit New Zealand

Transport Act (1962)
RS 16 (NZ)

Traffic Regulations (1976)
227 (NZ)

Underwood (1995)
Road Engineering Practice. Perth, WA: Monash University

Update (1998)
Transport Retort. 21/2. London: Transport 2000

Wardman, M; Hatfield, R; & Page, M (1997)
The UK national cycling strategy: can improved facilities meet the targets? *Transport Policy* 4 (2) pp 123–133. UK

Watkins, SM (1984)
Cycling Accidents. In Allott and Lomax (1991), *Cyclists and roundabouts: a review of literature.* Goldaming, UK: Cyclist's Touring Club

Welleman, T (1997)
The Dutch bicycle master plan, 1990–96. In Tolley R, *The greening of Urban Transport.* (2nd ed) Chichester, UK: John Wiley

West-Oram, F (1991)
The one-third reduction target. *Traffic Engineering and Control,* 32(4), pp 359–63

Wheeler, AH; Leicester, MAA & Underwood, G (1993)
Advanced stop lines for cyclists. *Traffic Engineering and Control,* 34(2)

Whitelegg, J (1993)
Time Pollution. *The Ecologist,* August

Wood, K (1991)
It will revolutionise transport in New Zealand. In *Proceedings of the New Zealand Land Transport Symposium,* Wellington: Transit New Zealand

Wood, K (1994)
Trip report: Europe and N America. Unpublished

Wood, K (1997)
Trip report: N America and Europe. Unpublished

Wright, C (1991)
Urban Transport, Health and Synergy, *Transportation Quarterly*. July

Appendix A: Recommendations

Abbreviations

Abbreviations for suggested action parties are:

ACC	Accident Compensation Corporation
EP	Education Providers
LTSA	Land Transport Safety Authority
MoT	Ministry of Transport
TF	Transfund
TLAs	Territorial Local Authorities
TNZ	Transit New Zealand
P	Police

Strategy and General — **Suggested action**

1 Set a target of reducing the cycling fatality rate to no more than 20 per billion kilometres cycled by 2008 (4.2). MoT, LTSA

2 Set a target of a doubling of cycle numbers within 6 years, then a further doubling within 10 years, to reach a national figure of 16% of commuters on cycles by 2016 (5.7). MoT, LTSA

3 Adopt a 'Road danger reduction' approach to road safety (11.6). MoT, LTSA

4 Define the rights and responsibilities of all road users (10.9). MoT

5 Adopt a national cycling strategy (8.3). LTSA, MoT

6 Investigate the possibility that New Zealand legislation is indirectly promoting unsafe road conditions through detailed give-way rules and no-blame legislation (11.8). MoT, LTSA

7 Develop a new vision for road safety for all road users, based on the proposals by The Institution of Civil Engineers (1996) and the Road Danger Reduction Forum (1997) (11.9). LTSA, MoT

8 Ensure that LTSA and ACC data can be compared on the same basis (9.3). LTSA, ACC

9 Develop a framework for evaluation of cycle facilities, using cost-benefit analysis but also recognising the equity issues of 'no-go' areas for cyclists (8.8). Transfund

Data recording

10 Investigate methods of improving the accuracy of information gathering (4.20). LTSA, P

11 Investigate methods of minimising bias in the LTSA database (4.21). LTSA, P

Suggested action

12 Encourage reporting of all cyclist-pedestrian and cyclist-cyclist crashes, and falls due to poor surfaces. Falls could be reported on a separate form and passed to the local authority rather than the LTSA (2.3). LTSA, P, TLAs

13 Specifically record and investigate crashes where a cyclist was crowded (4.18). LTSA, P

14 Investigate improved recording of the factors in Table 4.3 to assist cycle facility designers. These include: Did not stop at traffic signals, Swerved..., Wrong way in one-way street, Wandering or wobbling, Not using cycleway, Riding on footpath and Road slippery, uneven or narrow (4.19). LTSA, P

15 Provide police training in advanced crash investigation (as recommended in Brown, 1996) (4.20). P, LTSA

16 Revise the form used for crash investigation (TAR 565) to treat drivers, cyclists and pedestrians in the same way (4.21). LTSA, P

Education and enforcement

17 Use speed limit enforcement margins that are as low as practicable (5.2). P, LTSA

18 Make drivers more aware of their psychological limitations (11.3). LTSA, EP

19 Make drivers more aware of the special limitations of children and more responsible for their safety. (11.3) LTSA, EP

20 Amend the Road Code to show cases where drivers give way to cyclists, and give specific recommendations to drivers on clearances for overtaking cyclists (11.7). LTSA

21 Introduce practical road safety training for school children (11.7). LTSA, EP

22 Consider producing a New Zealand cycling skills book similar to Franklin (1997) (11.7). LTSA

23 Incorporate the concept of primary and secondary riding positions into New Zealand cycling education (11.7). LTSA

Planning and policy

24 Fully integrate cycle provision into road planning and design methodologies (4.22). MoT, LTSA, TF, TLAs

25 Implement the LTSA proposal permitting 30 km/h speed limits (10.6). LTSA, TLAs

Planning and policy (continued)

Suggested action

26 Consider ~~20~~ 30 (corrected 2008, see 5.2) km/h speed limits for use in selected residential streets, with priority for cyclists and pedestrians (5.2). LTSA, TLAs

27 Continue cycle lanes through junctions whenever cycles have priority over cross traffic, including signalised junctions (7.3). TNZ, TLAs

28 Reserve a suitable road surface colour for highlighting cycle lanes where needed (7.3). TNZ, LTSA, TLAs

29 Allow cyclists to go straight ahead from a lane that is left turn only for general traffic, unless specifically prohibited (7.7). LTSA, TNZ, TLAs

30 Consider wider use of the 4 way stop (7.10). LTSA, TLAs

31 Consider allowing cyclists to treat a Stop sign as a Give Way (7.10). LTSA

32 Prefer junctions controlled by 'Stop' signs for cycle safety (4.3). TNZ, TLAs, LTSA

33 Combined bus-cycle lanes are acceptable unless bus or cycle traffic is very heavy or bus speeds are high (4.16). TNZ, TLAs, LTSA

34 Safe cycle routes to school should avoid situations where children have to turn right without either special protection or a 30 km/h zone. Movement codes JA, AA, GC, HA, and LB need special care (5.5). LTSA, TNZ, TLAs

Standards — **Suggested action all LTSA, Transfund, TNZ**

35 Adopt or develop a good quality cycle standard for New Zealand. Austroads 14 will need revision (Table 8.1) before it is adequate (8.3).

36 Develop cycle-friendly roundabout designs (7.9).

37 Develop cycle lane markings which cannot be confused with edge lines, sealed shoulders and flush medians, and publicise the new system. A suggested system is shown in Figure 6.3 (6.8).

38 Develop standards for cycle track crossings (7.4).

39 Abandon the practice of putting a chicane in a traffic island used by cyclists (7.4).

40 Review options for heavy left turning traffic crossing a cycle lane (7.7).

41 Introduce guidelines for advanced stop lines for cycles at traffic signals (7.8).

42 Investigate the introduction of 'hook turns' as an option for cycles (7.8).

43 Develop guidelines on ending cycle facilities (6.14).

44 Develop recommendations for controlling traffic speeds at junctions (7.2).

Design — **Suggested action all Transfund, TNZ, TLAs**

45 Limit new cycle lanes to situations within the safe traffic speed/volume limits of Figure 6.2, and phase out existing non-complying lanes (6.6).

46 Cycle lane widths should be 1.8 m preferred, 1.5 m minimum and 2.5 m maximum. These figures may include the width of the lane line but must not include uneven surfaces unsuitable for cycling. Additional width is needed close to fixed objects or where cyclists have to stop (6.6).

47 Cycle lanes are inappropriate where there is high parking turnover (6.6).

48 Do not use combined parking-cycle lanes, but mark parking bays and a cycle lane separately, with a safety strip (6.6).

49 Cycle track widths should be: seal 1.5 m minimum, clearance 2.5 m minimum. Greater widths are needed unless cycle numbers are very low (6.9).

50 Cycle track designs should prevent motor vehicle parking close to junctions, entrances or the track edge (6.9).

51 Two-way or contra-flow cycle tracks alongside a road need special care at junctions (6.9).

52 Kerb side traffic lanes in a 50 km/h zone should be 4.2 m minimum width. In a 30 km/h zone the minimum width should generally be 3.85 m but a *maximum* width of 2.6 m may be used over short distances (6.7).

53 Traffic calming designs should be cycle-friendly and should not introduce pinch points. Large schemes tend to be cheaper in the long run (6.12).

54 Design all new roundabouts to cycle-friendly standards, or provide alternative routes (7.9).

55 Review all existing roundabouts for cycle-friendliness and redesign or by-pass as needed (7.9).

56 Allow combined cycle-bus lanes, for cycle use in the same direction as buses, or in both directions where appropriate. Recommended minimum widths are 4.2 m for cycles in one direction or 6.2 m for cycles in both directions. Where a bus

route is on a separate road a minimum width of 5.15 m is need for sharing with cycles. Greater widths are needed on bends (6.10).

57 Avoid or eliminate pinch points where cyclists could be trapped between an overtaking vehicle and a fixed object (6.11).

Legal **Suggested action all MoT**

58 Revise the legal definitions of cycle and cyclist to clarify the position of young cyclists riding on footpaths, define when adult cyclists may ride on the footpath and set minimum ages for cycling in various situations (10.2).

59 Define in law the concepts of advisory cycle lane, mandatory cycle lane, bus-cycle lane, cycle track, and foot-cycle track (10.3).

60 Soften the requirement that cyclists use cycle facilities where available (10.4).

61 Ensure that cycle tracks can be provided on or off road without legal restraint, and with cycle priority where appropriate (10.5).

62 Consider a universal parking ban in cycle lanes (10.7).

Maintenance **Suggested action all TNZ, TLAs**

63 Maintain a smooth surface at the road edges, where cyclists ride (4.18).

64 Design cycle tracks for easy maintenance (6.9).

65 Maintain cycle tracks regularly (6.9).

Suggestions for further research

Suggested action all Transfund, LTSA, Universities

66 Investigate further the relative safety risks of additional trips by cycle and motor vehicle, for high risk and average risk road users, and for cities with high and low cycle use (4.2).

67 Investigate the high rate of citing conspicuity as a factor in cycle crashes (4.20).

68 Check the change in cyclist's risk between the 1989–90 and 1997 Household Travel Surveys when the latter is published (4.22).

69 Investigate applying benefit/cost analysis to speed limits (5.2).

70 Locate or undertake research on social attitudes to vehicle use as a baseline for future surveys (11.7).

71 Investigate the safety effects of using road space for cycle facilities rather than as a flush median (6.3).

72 Investigate methods of reducing the cost of non-reportable crashes (9.4).

73 Check the possibility that some non-reportable crashes are fatal (9.4).

74 Seek to learn more about non-reportable crashes (9.5).

75 Make a study similar to this, looking at pedestrian safety (12.2).

Appendix B
Crash data summaries by movement code

The findings on each of the selected vehicle movement codes are summarised in Tables B.1 to B.14. A series of standard factors have been considered in all cases but are sometimes omitted from the tables where irrelevant. Additional factors are considered where needed.

Notes on the tables are given below.

- Most vehicle movement codes are effectively two different situations, depending on whether the cycle is the key vehicle or vehicle 2, 3 etc. The two cases are reviewed separately.
- Totals are sometimes inconsistent because of missing data and the omission of two minor junction types: Y and multileg.
- Assessment of where the contributory factors focussed on driver or cyclist ignores neutral factors such as poor visibility.
- A breakdown by age is given where it seems likely to be interesting and numbers are sufficient for the breakdown to be useful.
- A star (*) is used to indicate an additional digit: 10* (Driver alcohol) could be 100, 101, 102 etc.
- Bold figures are used for totals, and figures which are a third or more of the total for that column (except contributory factors focussed exclusively on the cyclist or driver, or cases where the total is less than 6).

Table B.1 Crash Type FA: Rear end of slow vehicle

Contributing Factor Codes	Description	Cycle shown by: Bold Arrow		Light Arrow	
		Fatal	Seri-ous	Fatal	Seri-ous
Totals	(Fatal injuries 1980 - 96, serious injuries 1994 - 6)	**-**	**1**	**73**	**36**
171	Driver following too closely	-	-	-	5
139	Driver too far left	-	-	5	8
R,E	Straight road or easy curve	-	1	**72**	**35**
B,F, DO, TO	Daylight or street lights on	-	1	**50**	**29**
30*	Cyclist alcohol	-	-	3	-
40* (not 406-7)	Cyclist, specific faults	-	-	2	-
406, 42*-45*	Cyclist inattentive etc	-	-	10	1
407, 931-2-5	Cycle, no or inadequate lights, or dark clothing	-	-	24	4
31*	Cyclist too fast	-	-	-	-
10*	Driver alcohol	-	-	24	2
22* to 25*	Driver inattentive etc	-	1	**28**	**24**
11*	Driver too fast	-	-	8	1
X	Crossroads	-	-	1	1
T	T junction	-	1	13	3
D	Driveway	-	-	1	-
	Not at a junction	-	-	**58**	**32**
T, D	In twilight or darkness	-	-	**38**	8
M, L, H, S	In rain, poor visibility or strong wind	-	-	14	1
W, I	On wet or icy road	-	-	13	1
	In urban area (speed limit < 50 km/h)	-	1	24	9
Contributory factors focussed exclusively on cyclist		-	-	17	3
Contributory factors focussed exclusively on driver		-	-	38	26

Of 10 crashes audited (plus 1 card missing), 2 showed speeding as a factor on the crash report but not on the database. A further 3 crashes were possibly wrongly coded.

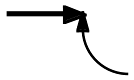
Contributory factor 931 (no cycle headlight: irrelevant for this crash type) was cited in 7 fatal crashes. Four of these cases were associated with factor 932 (no cycle tail light) and so are unlikely to be wrong coding. Only one of them was associated with a third vehicle; another cyclist who was seriously injured.

Five fatal and 7 serious injury crashes were in daylight and an urban area, with no adverse weather conditions other than a low sun (3 cases).

Factor 334 (cyclist failed to keep left) was cited as the only contributing factor in one serious crash.

- The slow vehicle is almost always a cycle.
- This type of crash seems to affect experienced cyclists more than inexperienced, with the 20–59 year age group particularly badly affected.
- The relative frequency of serious injury crashes has fallen since 1980–87.
- Cyclist conspicuity was cited as a contributing factor in a high proportion of crashes.
- A high proportion of crashes happened at night, away from a junction and in areas with a speed limit of more than 50 km/h.
- A high proportion of drivers were cited as affected by alcohol.

Table B.2 Crash type LB: Right turn against

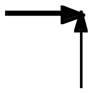


Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal injuries 1980 - 96, serious injuries 1994 - 6)		**14**	**50**	**13**	**24**
32*, 48*	Cyclist failed to give way	-	-	10	**16**
30*	Cyclist alcohol	-	-	1	-
40* (not 406-7)	Cyclist, specific faults	1	1	-	-
406, 42*-45*	Cyclist inattentive etc	2	2	**5**	9
407, 931-2-5	Cycle, no or inadequate lights, or dark clothing	3	4	-	-
31*	Cyclist too fast	2	1	-	-
12*, 28*	Driver failed to give way	**9**	**45**	1	5
10*	Driver alcohol	2	5	2	-
22* to 25*	Driver inattentive etc	3	**17**	1	6
11*	Driver too fast	-	-	1	2
X	Crossroads	3	15	2	**8**
T	T junction	**7**	**22**	**7**	**8**
R	Roundabout	-	1	-	4
D	Driveway	1	10	4	4
T	Traffic signals	2	9	2	2
G	Give way	4	13	-	**12**
S	Stop	2	3	1	2
N	No junction control	6	**25**	**10**	**8**
T, D	In twilight or darkness	**5**	11	**5**	2
M, L, H, S	In rain, poor visibility or strong wind	**5**	7	-	2
W, I	On wet or icy road	**5**	8	1	3
	In urban area (speed limit < 50 km/h)	**13**	**49**	**10**	**22**
Cyclists age	0 - 9	1	-	2	-
	10 - 14	4	7	4	10
	15 - 19	1	8	1	3
	20 - 59	**8**	**30**	4	**10**
	60 +	-	-	1	-
Contributory factors focussed exclusively on cyclist		5	3	7	16
Contributory factors focussed exclusively on driver		7	41	1	5

Of 11 crashes audited (plus 1 card not found), 1 was wrongly coded. The cyclist was frequently not seen.

- Serious injuries show some bias towards the 20–59 age group, mainly cyclists who are not turning.
- The relative frequency of serious injury crashes has fallen slightly since 1980–87.
- A high proportion of fatal crashes are at uncontrolled intersections, particularly where the cyclist is turning. For serious injuries the emphasis is more on cyclist who are not turning.
- Most crashes are in urban areas. All junction types are represented but with some emphasis on crossroads and T junctions.
- The predominant contributing factor cited is failure to give way.

Table B.3 Crash Type HA: Right angle crossing, no turns



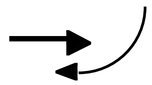
Contributing Factor Codes	Description	Cycle shown by: Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
Totals (Fatal 1980 - 96, serious 1994 - 6)		**11**	**28**	**14**	**35**
32*, 48*	Cyclist failed to give way	**8**	**13**	4	4
30*	Cyclist alcohol	-	-	-	-
40* (not 406-7)	Cyclist, specific faults	1	3	1	1
406, 42*-45*	Cyclist inattentive etc	3	4	2	2
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	1	1	6
31*	Cyclist too fast	1	1	-	1
12*, 28*	Driver failed to give way	-	6	**5**	**19**
10*	Driver alcohol	1	-	1	1
22* to 25*	Driver inattentive etc	-	3	4	7
11*	Driver too fast	-	-	-	-
X	Crossroads	**7**	**15**	**12**	**16**
T	T junction	1	4	1	3
R	Roundabout	-	-	-	**12**
D	Driveway	3	6	1	4
	Not at a junction	-	-	-	-
T	Traffic signals	-	5	3	5
G	Give way	3	**10**	4	**22**
S	Stop	**4**	4	4	4
N	No junction control	**4**	9	2	4
T, D	In twilight or darkness	1	1	3	**14**
M, L, H, S	In rain, poor visibility or strong wind	2	3	2	9
W, I	On wet or icy road	2	5	3	10
	In urban area (speed limit < 50 km/h)	**10**	**26**	**11**	**28**
Cyclist's age	0 - 9	**5**	2	3	2
	10 - 14	2	**11**	1	9
	15 - 19	-	4	1	7
	20 - 59	1	9	**6**	**16**
	60 +	2	1	3	-
Contributory factors focussed exclusively on cyclist		9	19	9	12
Contributory factors focussed exclusively on driver		-	8	5	17

Of the 11 crashes audited 1 was wrongly coded and another possibly wrongly coded. The cyclist was frequently not seen.

There seems to be frequent confusion between this movement code and codes KA and KB.

- The fatal crashes show a high proportion of young and old cyclists but this is not reflected in the serious crash data.
- The relative frequency of serious injury crashes has risen since 1980–87, with a slight absolute increase.
- A high proportion of serious injury crashes are at Give Way signs.
- A high proportion of serious injury crashes with the cyclist approaching from the right are at roundabouts.
- Most crashes are at crossroads and in urban areas.
- The predominant contributing factor cited is failure to give way.

Table B.4 Crash Type JA: Crossing vehicle turning right



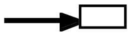
Contributing Factor Codes	Description	Bold Arrow: Fatal	Bold Arrow: Serious	Light Arrow: Fatal	Light Arrow: Serious
Totals (Fatal injuries 1980 - 96, serious injuries 1994 - 6)		**-**	**24**	**33**	**33**
404	Cycling on footpath	-	-	-	5
32*, 48*	Cyclist failed to give way	-	-	**27**	**25**
30*	Cyclist alcohol	-	-	1	-
40* (not 406-7)	Cyclist, specific faults	-	-	-	5
406, 42*-45*	Cyclist inattentive etc	-	-	**11**	9
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	2	3	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	**23**	1	-
10*	Driver alcohol	-	-	6	1
22* to 25*	Driver inattentive etc	-	7	2	2
11*	Driver too fast	-	-	2	1
X	Crossroads	-	3	2	4
T	T junction	-	**14**	**19**	**17**
R	Roundabout	-	1	-	-
D	Driveway	-	3	**12**	**12**
T	Traffic signals	-	1	2	1
G	Give way	-	**16**	**11**	9
S	Stop	-	1	-	5
N	No junction control	-	6	**19**	**18**
T, D	In twilight or darkness	-	6	**15**	4
M, L, H, S	In rain, poor visibility or strong wind	-	5	5	6
W, I	On wet or icy road	-	6	4	6
	In urban area (speed limit < 50 km/h)	-	**19**	**20**	**27**
Cyclist's age	0 - 9	-	-	10	6
	10 - 14	-	2	7	**13**
	15 - 19	-	2	6	5
	20 - 59	-	**16**	8	8
	60 +	-	1	2	-
Contributory factors focussed exclusively on cyclist		-	1	24	27
Contributory factors focussed exclusively on driver		-	21	2	2

Cycle shown by: Bold Arrow / Light Arrow

Of 9 crashes audited, 2 were possibly wrongly coded. Two crashes had unhelpful cause codes.

- None of the cyclists who were going straight through were killed.
- Young cyclists turning right are particularly vulnerable.
- The relative frequency of serious injury crashes has risen slightly since 1980–87, but absolute numbers have declined slightly.
- A high proportion of crashes are at Give Way signs or uncontrolled intersections.
- Most crashes are in urban areas, principally at T junctions but also at driveways.
- The predominant contributing factor cited is failure to give way.

Table B.5 Crash Type EA: Hit parked vehicle



Contributing Factor Codes	Description	Bold Arrow: Fatal	Bold Arrow: Serious	No Arrow: Fatal	No Arrow: Serious
Totals (Fatal 1980 - 96, serious 1994 - 6)		**9**	**35**	**2**	**-**
224, 504	Hit by car door	**3**	**16**	-	-
720	Pedestrian, alcohol affected	1	-	-	-
139	Car too far left (hit cycle)	-	-	1	-
26*, 606	Driver stopped or parked incorrectly	2	4	-	-
26*, 46*	Cycle stopped or parked (hit by car)	-	-	2	-
30*	Cyclist alcohol	-	2	-	-
40* (not 406-7)	Cyclist, specific faults	1	-	-	-
406, 42*-45*	Cyclist inattentive etc	**5**	**14**	-	-
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	(2)	-
31*	Cyclist too fast	-	3	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	-	-
22* to 25*	Driver inattentive etc	-	-	-	-
11*	Driver too fast	-	-	-	-
X	Crossroads	-	2	-	-
T	T junction	2	4	-	-
T, D	In twilight or darkness	2	9	2	-
M, L, H, S	In rain, poor visibility or strong wind	3	2	1	-
W, I	On wet or icy road	3	2	-	-
	In urban area (speed limit < 50 km/h)	**7**	**30**	-	-
Contributory factors focussed exclusively on cyclist		2	16	1	-
Contributory factors focussed exclusively on driver		3	17	-	-

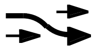
Cycle shown by: Bold Arrow / No Arrow

The bracketed figure indicates two cases where the situation was coded another way (26*, 46*).

Of 5 crashes audited (plus 2 cards not found), one was possibly wrongly coded. Another was a cycle race with the road closed and arguably a sporting rather than a road incident.

- The serious injury crashes show a bias towards the 15–19 years age group.
- The relative frequency of serious injury crashes has increased since 1980–87, with a slight absolute increase.
- Most crashes are away from junctions, but with some incidents near crossroads and T junctions.
- Most crashes are in urban areas.
- The predominant contributing factors cited are inattentive cyclists and drivers opening car doors into a cyclist’s path.
- (2008) A cyclist hitting an opening car door is now a separate code: see Appendix G.

Table B.6 Crash Type AA: Pulling out or changing lane to right

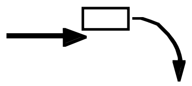


Contributing Factor Codes	Description	Cycle shown by: Bold Arrow – Fatal	Bold Arrow – Serious	Light Arrow – Fatal	Light Arrow – Serious
Totals (Fatal injuries 1980 - 96, serious injuries 1994 - 6)		**13**	**21**	**3**	**2**
B	Bus involved	1	-	-	-
	Strong wind	1	-	1	-
402, 404	Cyclist not using cycleway or riding on the footpath	2	-	1	-
422, 426	Cyclist failed to check behind when changing lane etc	**10**	**17**	1	-
32*, 48*	Cyclist failed to give way	1	-	-	-
30*	Cyclist alcohol	1	-	-	-
40* (not 406-7)	Cyclist, specific faults	2	-	1	-
406, 42*-45*	Cyclist inattentive etc	**13**	**17**	1	-
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	2	-	-	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	-	-
22* to 25*	Driver inattentive etc	1	-	-	2
11*	Driver too fast	-	1	-	-
X	Crossroads	-	3	-	-
T	T junction	3	4	-	-
D	Driveway	1	-	-	-
	Not at a junction	**9**	**13**	3	2
T	Traffic signals	-	2	-	-
G	Give way	-	2	-	-
S	Stop	-	1	-	-
N	No junction control	4	3	-	-
T, D	In twilight or darkness	4	3	2	-
M, L, H, S	In rain, poor visibility or strong wind	1	3	2	-
W, I	On wet or icy road	1	3	1	-
In urban area (speed limit < 50 km/h)		**8**	**17**	2	2
Contributory factors focussed exclusively on cyclist		12	19	2	-
Contributory factors focussed exclusively on driver		-	-	1	2

Of 8 crashes audited, 4 were possibly wrongly coded. In one case the impact point was on the edge line, and yet it was supposed to be the cyclist who had swerved to the right.

- Serious injury crashes show a bias towards younger (0–14) and elderly cyclists.
- The relative frequency of serious injury crashes has risen dramatically since 1980–87.
- A high proportion of serious injury crashes are away from junctions, but with some incidents near crossroads and T junctions.
- Most crashes are in urban areas.
- The predominant contributing factors cited are cyclists failing to check behind before pulling out, and inattention.

Table B.7 Crash Type GC: Stopped or turning from left side

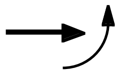


Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
Totals (Fatal 1980 - 96, serious 1994 - 6)		**1**	**1**	**23**	**17**
426	Cyclist failed to check behind	-	-	**15**	**12**
361, 364	Cyclist turned right from incorrect lane or from left side of road	1	-	1	**9**
32*, 48*	Cyclist failed to give way	-	-	1	2
30*	Cyclist alcohol	-	-	1	-
406, 42*-45*	Cyclist inattentive etc	1	-	**18**	**12**
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	3	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	1	1
22* to 25*	Driver inattentive etc	-	1	3	-
11*	Driver too fast	-	-	1	1
X	Crossroads	-	-	5	2
T	T junction	1	-	**9**	**7**
D	Driveway	-	1	5	**8**
	Not at a junction	-	-	3	-
G	Give way	1	-	6	4
S	Stop	-	-	2	1
N	No junction control	-	1	**12**	**11**
T, D	In twilight or darkness	-	-	2	1
M, L, H, S	In rain, poor visibility or strong wind	-	-	1	3
W, I	On wet or icy road	-	-	1	5
	In urban area (speed limit < 50 km/h)	1	1	**12**	**10**
Contributory factors focussed exclusively on cyclist		1	-	17	15
Contributory factors focussed exclusively on driver		-	1	-	-

Of 7 crashes audited, 3 were probably wrongly coded and another had a wrong cause code. All of the audited crashes involved a moving second vehicle.

- Serious crashes show a bias towards younger and elderly cyclists (10–14 and 60+ years).
- The relative frequency of serious injury crashes is much lower than the 1980–87 level.
- The most frequent locations are at uncontrolled crossroads and T junctions.
- More than half the crashes are in urban areas.
- The predominant contributing factors cited are cyclists failing to check behind before pulling out, and cyclist’s inattention.

Table B.8 Crash Type GB: Side swipe to left side

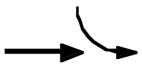


Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal 1980 - 96, serious 1994 - 6)		**15**	**12**	**2**	**1**
157	Driver cut in	-	2	-	-
160, 162, 165	Driver turned left from incorrect lane or near road centre	1	1	1	-
356	Cyclist overtaking on left	**5**	2	-	1
404	Cyclist riding on footpath	4	3	-	-
437	Cyclist misjudged intentions of another party	3	1	-	-
T	Motor vehicle was a truck	**12**	3	2	-
T, D	Truck in private driveway	5	2	1	-
32*, 48*	Cyclist failed to give way	-	1	-	-
40* (not 406-7)	Cyclist, specific faults	4	3	1	-
406, 42*-45*	Cyclist inattentive etc	**6**	2	-	-
31*	Cyclist too fast	1	-	-	-
12*, 28*	Driver failed to give way	-	2	1	-
10*	Driver alcohol	1	-	-	-
22* to 25*	Driver inattentive etc	2	3	1	-
11*	Driver too fast	-	-	-	-
X	Crossroads	**6**	1	1	-
T	T junction	2	3	-	-
R	Roundabout	1	1	-	-
D	Driveway	**5**	**6**	1	1
	Not at a junction	1	-	-	-
T	Traffic signals	4	-	-	1
G	Give way	2	2	1	-
N	No junction control	**8**	**9**	1	-
T, D	In twilight or darkness	1	-	-	-
M, L, H, S	In rain, poor visibility or strong winds	3	-	-	-
W, I	On wet or icy road	3	-	-	-
	In urban area (speed limit < 50 km/h)	**13**	**12**	2	1
Contributory factors focussed exclusively on cyclist		11	6	-	1
Contributory factors focussed exclusively on driver		2	5	1	-

Of 8 crashes audited (plus 1 card missing), none seemed wrongly coded.

- Most of the fatal injuries were in crashes with a truck, frequently at a private entrance (includes garage, commercial premises etc).
- The serious crashes suggest a bias towards cyclists aged 60 + years.
- The relative frequency of serious injury crashes has increased since 1980–87, with an absolute increase.
- The most common locations are crossroads and driveways.
- Most crashes are in urban areas.
- No predominant contributing factor was cited.

Table B 9 Crash Type KA: Left turn in

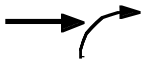


Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal 1980 - 96, serious 1994 - 6)		**1**	**9**	**9**	**8**
32*, 48*	Cyclist failed to give way	-	-	**6**	**7**
30*	Cyclist alcohol	-	-	-	-
406, 42*-45*	Cyclist inattentive etc	-	-	**3**	2
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	-	1
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	1	**9**	-	-
10*	Driver alcohol	-	1	1	-
22* to 25*	Driver inattentive etc	-	**4**	1	-
11*	Driver too fast	-	-	-	-
X	Crossroads	-	1	1	**4**
T	T junction	1	**4**	2	-
D	Driveway	-	2	**6**	**4**
T	Traffic signals	-	-	-	-
G	Give way	-	**5**	1	2
S	Stop	-	-	-	2
N	No junction control	1	**4**	**8**	**4**
T, D	In twilight or darkness	-	**3**	2	2
M, L, H, S	In rain, poor visibility or strong wind	-	1	-	2
W, I	On wet or icy road	-	-	-	2
	In urban area (speed limit < 50 km/h)	-	**9**	**7**	**7**
	Cyclist's age 0-9	-	1	2	2
	Cyclist's age 10-14	-	-	2	3
	Cyclist's age 15-19	-	1	2	2
	Cyclist's age 20-59	1	**7**	**3**	1
	Cyclist's age 60+	-	-	-	-
Contributory factors focussed exclusively on cyclist		-	-	7	8
Contributory factors focussed exclusively on driver		1	9	2	-

Of 7 crashes audited (plus 1 card missing), four seemed to be wrongly coded. A further case was unclear. Movement codes KA and KB both seem to be easily confused with movement code HA.

- The serious injury crashes suggest a bias towards cyclists aged 15–19 and 60+. The breakdown above suggests that these cyclists are usually turning, often at driveways, while cyclists aged 20–59 are more likely to be hit while going straight through a junction.
- The relative frequency of serious injury crashes has decreased slightly since 1980–87.
- The most common locations are Driveways, uncontrolled junctions or junctions controlled by Give Way signs. T junctions and crossroads are well represented.
- Most crashes are in urban areas.
- The predominant contributing factor cited is failure to give way.

Table B 10 Crash Type KB: Right turn in

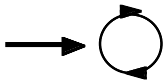


	Cycle shown by:	Bold Arrow		Light Arrow	
Contributing Factor Codes	Description	Fatal	Serious	Fatal	Serious
Totals (Fatal 1980 - 96, serious 1994 - 6)		**-**	**5**	**11**	**9**
404	Cyclist riding on footpath	-	2	-	-
32*, 48*	Cyclist failed to give way	-	-	**8**	**4**
30*	Cyclist alcohol	-	-	-	-
40* (not 406-7)	Cyclist, specific faults	-	2	-	-
406, 42*-45*	Cyclist inattentive etc	-	1	**4**	1
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	2	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	2	-	1
10*	Driver alcohol	-	1	3	-
22* to 25*	Driver inattentive etc	-	2	1	2
11*	Driver too fast	-	-	1	1
X	Crossroads	-	-	2	3
T	T junction	-	2	**6**	**3**
R	Roundabout	-	-	-	1
D	Driveway	-	3	3	2
T	Traffic signals	-	-	1	**3**
G	Give way	-	1	1	**3**
S	Stop	-	-	2	1
N	No junction control	-	4	**7**	2
T, D	In twilight or darkness	-	-	4	1
M, L, H, S	In rain or poor visibility	-	-	-	2
W, I	On wet or icy road	-	1	1	1
In urban area (speed limit < 50 km/h)		-	5	**10**	**8**
	Cyclist's age 0-9	-	-	3	1
	Cyclist's age 10-14	-	2	1	2
	Cyclist's age 15-19	-	1	-	**4**
	Cyclist's age 20-59	-	2	2	2
	Cyclist's age 60+	-	-	**5**	-
Contributory factors focussed exclusively on cyclist		-	3	6	5
Contributory factors focussed exclusively on driver		-	2	-	3

Of 7 crashes audited, 6 seemed wrongly coded. Movement codes KA and KB both seem to be easily confused with movement code HA.

- The cyclist's ages suggests a bias towards older and younger riders when the cycle is second vehicle (turning), apparently with a heavy bias towards under-10 year olds.
- The relative frequency of serious injury crashes has decreased slightly since 1980–87.
- The most common locations are T junctions, with crossroads and driveways also well represented.
- Most crashes are in urban areas.
- The predominant contributing factor cited was failure to give way, followed by inattention.

Table B 11 Crash Type MB: U turn



Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Serious	Light Arrow Fatal	Light Arrow Serious
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal 1980 - 96, serious 1994 - 6)		**-**	**4**	**9**	**7**
427	Cyclist did not check before U turn	-	-	**8**	**7**
227	Driver did not check before U turn	-	3	-	-
30*	Cyclist alcohol	-	-	-	-
40* (not 406-7)	Cyclist, specific faults	-	-	-	1
406, 42*-45*	Cyclist inattentive etc	-	-	**8**	**7**
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	1	-	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	1	-
22* to 25*	Driver inattentive etc	-	-	-	**3**
11*	Driver too fast	-	-	1	-
T	T junction	-	-	1	1
D	Driveway	-	1	-	1
	Not at a junction	-	3	**8**	**5**
T, D	In twilight or darkness	-	1	2	-
M, L, H, S	In rain, poor visibility or strong wind	-	-	-	1
W, I	On wet or icy road	-	1	1	1
	In urban area (speed limit < 50 km/h)	-	3	1	**5**
Contributory factors focussed exclusively on cyclist		-	1	8	7
Contributory factors focussed exclusively on driver		-	2	-	-

Of 7 crashes audited, 4 appear to be wrongly coded.

- The serious crash data suggests that young and old cyclists are most at risk.
- The relative frequency of serious injury crashes has not changed since 1980–87.
- There are no common locations.
- Most fatal crashes are outside urban areas.
- The predominant contributing factors cited were failure to check before making the turn, and inattention.
- (2008) There are now separate codes for the second vehicle turning into and away from the direction of the key vehilce. See Appendix G.

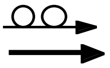
Table B.12 Crash type AC: Cutting in or changing lane to left

Contributing Factor Codes	Description	Bold Arrow Fatal	Bold Arrow Serious	Light Arrow Fatal	Light Arrow Serious
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal 1980 - 96, serious 1994 - 6)		**3**	**1**	**9**	**8**
B	Bus involved	-	-	-	-
171	Driver following too closely	-	-	-	2
197	Driver swerved to avoid vehicle	-	-	2	2
32*, 48*	Cyclist failed to give way	-	-	-	-
30*	Cyclist alcohol	1	-	1	-
40* (not 406-7)	Cyclist, specific faults	-	-	-	-
406, 42*-45*	Cyclist inattentive etc	1	1	1	1
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	1	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	1	-
22* to 25*	Driver inattentive etc	-	-	**5**	**5**
11*	Driver too fast	-	-	1	-
X	Crossroads	-	1	1	-
T	T junction	1	-	**3**	1
R	Roundabout	1	-	-	1
	Not at a junction	1	-	**5**	**5**
T	Traffic signals	-	-	1	-
G	Give way	-	-	-	2
S	Stop	-	1	-	-
N	No junction control	2	-	**3**	1
T, D	In twilight or darkness	-	-	1	-
M, L, H, S	In rain poor visibility or strong wind	-	-	-	2
W, I	On wet or icy road	-	-	-	1
	In urban area (speed limit < 50 km/h)	3	1	**5**	**4**
Contributory factors focussed exclusively on cyclist		2	1	1	-
Contributory factors focussed exclusively on driver		-	-	6	7

Of 7 crashes audited, 3 appear to be wrongly coded and a fourth inconclusive.

- The serious crash data suggests that cyclists aged 20+ are most at risk, with those aged 60 + years particularly at risk.
- The relative frequency of serious injury crashes shows a large increase since 1980–87.
- A majority of crashes are in urban areas.
- The predominant cause cited is inattentiveness.

Table B.13 Crash Type AF: Lost control (overtaken vehicle)

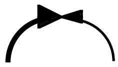
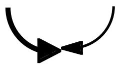
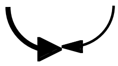
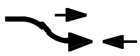


Contributing Factor Codes	Description	Bold Arrow: Fatal	Bold Arrow: Seri -ous	Light Arrow: Fatal	Light Arrow: Seri -ous
	Cycle shown by:	Bold Arrow		Light Arrow	
Totals (Fatal 1980 - 96, serious 1994 - 6)		**-**	**2**	**11**	**6**
B	Bus involved	-	-	1	1
800	Road surface	-	-	-	-
171	Driver following too closely	-	-	-	-
139	Driver too far left	-	-	-	-
356	Cyclist overtaking on left without due care	-	-	1	-
330	Cyclist failed to keep left	-	-	1	1
32*, 48*	Cyclist failed to give way	-	-	-	-
30*	Cyclist alcohol	-	-	-	-
40* (not 406-7)	Cyclist, specific faults	-	-	1	-
406, 42*-45*	Cyclist inattentive etc	-	2	**8**	**4**
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	-	-	-	-
31*	Cyclist too fast	-	-	-	-
12*, 28*	Driver failed to give way	-	-	-	-
10*	Driver alcohol	-	-	1	-
22* to 25*	Driver inattentive etc	-	-	1	-
11*	Driver too fast	-	-	-	-
X	Crossroads	-	-	1	-
T	T junction	-	2	1	-
R	Roundabout	-	-	-	1
D	Driveway	-	-	-	-
	Not at a junction	-	-	**8**	**5**
T	Traffic signals	-	-	1	-
G	Give way	-	1	-	-
S	Stop	-	-	-	-
N	No junction control	-	1	2	1
T, D	In twilight or darkness	-	-	1	-
M, L, H, S	In rain, poor visibility or strong wind	-	-	1	1
W, I	On wet or icy road	-	-	1	-
	In urban area (speed limit < 50 km/h)	-	2	**9**	**3**
Contributory factors focussed exclusively on cyclist		-	2	8	5
Contributory factors focussed exclusively on driver		-	-	1	-

Of 8 crashes audited, none appeared to be wrongly coded, but 1 had an incorrect cause code.

- The serious crash data suggests that cyclists aged less than 10 are rarely affected and cyclists aged 60+ are most at risk.
- The relative frequency of serious injury crashes has increased since 1980–87.
- Most crashes are in urban areas.
- The predominant contributing factor cited is cyclist's inattention.

Table B.14 Head-on (various types)

		Cycle shown by:	Bold Arrow Fatal	Bold Arrow Seri-ous	Light Arrow Fatal	Light Arrow Seri-ous
BA	**On straight**		**3**	**1**	**4**	**1**
BB	**Cutting corner**		**-**	**4**	**2**	**5**
BC	**Swinging wide**		**6**	**7**	**1**	**2**
BD	**Both or unknown**		**-**	**-**	**-**	**2**
BE	**Lost control**		**3**	**1**	**2**	**1**
AB	**Overtaking**		**2**	**1**	**5**	**3**
Totals (Fatal 1980 - 96, serious 1994 - 6)			**14**	**14**	**14**	**14**

Contributing Factor Codes	Description	Bold Fatal	Bold Seri-ous	Light Fatal	Light Seri-ous
425	Cyclist wrong way in 1 way street etc	2	1	-	1
338	Cyclist lost control	2	-	1	-
33* (not 338)	Cyclist failed to keep left	**5**	**10**	1	1
35*	Cyclist overtaking	1	-	-	-
13* (not 138)	Driver failed to keep left	-	-	3	**6**
15*	Driver overtaking	-	-	3	2
30*	Cyclist alcohol	3	1	-	-
40* (not 406-7)	Cyclist, specific faults	-	-	1	-
406, 42*-45* (not 425)	Cyclist inattentive etc	3	3	2	-
407, 931-2-5	Cycle no or inadequate lights, or dark clothing	1	-	2	1
31*	Cyclist too fast	3	3	-	-
10*	Driver alcohol	2	-	3	2
22* to 25*	Driver inattentive etc	-	-	3	2
11*	Driver too fast	-	-	3	1
T	T junction	1	**5**	1	**7**
D	Driveway	-	1	1	-
	Not at a junction	**12**	**8**	**10**	**7**
N	No junction control	1	3	2	4
T, D	In twilight or darkness	2	4	**6**	**5**
M, L, H, S, 90*	In rain, poor visibility or strong wind	3	2	3	3
W, I	On wet or icy road	1	2	2	3
	In urban area (speed limit < 50 km/h)	**7**	**9**	**8**	**8**
Contributory factors focussed exclusively on cyclist		12	13	5	3
Contributory factors focussed exclusively on driver		-	1	8	10

Of 20 crashes audited, 2 were possibly wrongly coded.

- Most crashes are not at a junction, but a significant minority are at T junctions.
- The relative frequency of serious injury crashes has increased since 1980–87.
- Most crashes are in urban areas, but with a relatively high proportion in rural areas.
- The predominant contributing factor cited is cyclist's failing to keep left, with drivers failing to keep left as a lesser factor.

Appendix C:
Audit of Traffic Accident Reports (TAR)

Reasons for selecting each crash audited (see 2.8) are:

T Ten percent sample

A Additional samples for crash types where numbers are small

O Special selection of crashes which looked 'odd' during initial review

Single capitals are used as abbreviations for East, Left, North, Right, South & West

Table C 1: Audited Traffic Accident Reports

No	Year	Comments	Reason for selection
FA: Rear end of slow vehicle—fatal			
10012	80	Stolen car, disqualified driver.	O
10069	82	Cause code wrong. Speed limit 50 km/h, driver's speed 60 km/h admitted: not cited on database.	T
00130	84	Card not found.	T
00048	85	Driver swerved L, sun weak excuse?	T
20009	87	Wrong cause code. Speed limit 50 km/h, driver 63 km/h on own admission, *at least 75 km/h* according to witness. Cyclist swerved, no other details, speeding not on database.	T
00177	88	No definite point of impact, another car 10–20 m ahead passed without trouble. Lane width 6.5 m.	O
10142	89	Very dark, heavy rain. Lane width 3.5 m.	T
00335	90	Wrong cause code. Speed limit 80 km/h, driver claimed ~70 km/h, accurate point of impact not obtainable, tyre marks 0.3 m from gravel of entrance, 15 m long. Lane width 3.3 m, car stopped 120 m from impact. *Cause unknown* on database with no factors cited.	O
20084	91	Wrong cause code. Bridge on Sumner causeway, cycle lane stops at bridge, lane width 4.0 m. Investigating officer said *Cycle lane not completed,* and *average speed on this section 60–70 km/h.* Recorded on database as *Wandering or wobbling* but in fact predictable.	T
00151	92	Lane width 5.3 m including shoulder (cycle lane?) 1.7 m (*report attached* and missing).	O
10030	95	Driver swerved to left; *Inattention.*	T
14119	94	Wrong coding, should be AA. Cycle key vehicle. Claimed speeds driver 10 km/h, cyclist 30 km/h, cyclist ended up 10 m in front of car. Cause code also wrong. Cyclist cited as *overtaking line of traffic* but both were doing this.	T
FA: Rear end of slow vehicle—serious			
21210	94	Driver hit cyclist on bridge, claimed blinded by low sun but direction given as S, time 07.10.	0
23615	94	Wrong coding, should be AA. Illegally parked car door opened (driver dropping off rear seat passenger), cyclist swerved. Point of impact 3.5 m from kerb.	T
01414	95	Car did not stop, no witnesses.	O
01808	96	Probable wrong coding, could be AA, FA, HA, NB. Events unclear but HA or NB look most likely. The events could probably have been made clear by more careful questioning of witnesses.	T
23365	96	Impact point in cycle lane: driver fell asleep.	A
LB: Right turn against—fatal			
10002	80	Card not found.	T
00053	85	Careless use causing death. Driveway, cyclist on footpath, *killed* (cyclist) *by dragging him up drive.* Cyclist's age 9 years.	O
00113	86	Driver *thought he wasn't going to cross.* Speed limit 50 km/h, driver stopped 50 m beyond point of impact. Cyclist's age 9 years.	T
20003	91	Driver failed to see cyclist, *statement on prosecution file.* Record incomplete.	T
00137	96	Wrong coding, should be GC or GE. Cyclist turned R from L side.	A
10042	96	Cycle headlight ~8 m from point of impact, batteries found separately, van unregistered.	O
LB: Right turn against—serious			
01325	94	Cycle key vehicle, driver braked when passenger yelled. Cyclist admitted no lights.	O
02393	94	Cycle key vehicle, false driver details given at scene. Third vehicle came out from cyclist's L, then stopped blocking path. Cyclist swerved R, collected by opposing car turning R. Not clear if third vehicle a contributory factor.	T
21052	94	Six lanes, cyclist on L lane. Low sun possibly contributory, sun visor down, driver could *see OK.* Cyclist swerved L before impact, which was 0.2 m out from projected kerb line.	T
22092	94	Roundabout. Cyclist said, *She was staring straight at me and I thought we had eye contact and that she had seen me. I was directly in front of her when she came forward into me. She was moving slowly* (15–20 km/h according to driver) Impact ~3 m from stop line. Twilight, cycle headlight on, Investigating officer said *cyclist had headlight on, wearing dark clothes.* Conspicuity not cited.	T
06105	95	Car turning into driveway.	T

No	Year	Comments	Reason for selection
LB: Right turn against—serious (continued)			
14532	95	Car turned across cycle, driver's description conflicts with witness, driver factors given as *OK.* No other factors given on TAR, but *driver failed to give way* on database.	T
02082	96	Cycle key vehicle. Cyclist not seen until he yelled. Car turning R on six lane highway, two vehicles had stopped for cyclist (traffic banked up from lights), cyclist came through on inside. Cyclist had right of way, but at fault?	T
12265	96	Cycle ran through Stop sign; car turning R.	T
12304	96	Cyclist coming downhill at speed. Driver thought he had time to turn in front of witness's car, did not see cycle.	O
22796	96	Roundabout, driver says cyclist was close behind another vehicle, hidden.	T
HA: Right angle crossing, no turns—fatal			
10038	84	Cycle second vehicle. Driver starting out in borrowed car, waited for car turning R across from ahead, did not see cyclist coming from R.	T
00017	90	Cycle key vehicle. Driver said *slow speed... when the boy came from nowhere. I didn't see him until he was in front of me. I had no chance to avoid him.* Investigating officer said, *No further action recommended: child cycled into path of oncoming vehicle.* T junction close by (recorded as T-junction on database) but child came from drive opposite and slightly offset. A third vehicle parked before driveway, directly opposite junction according to sketch but no dimensions given. Moving car stopped 26.8 m from point of impact, child about 65–75% of this according to diagram, both on opposite side of road. Vehicle travelled over top of child and cycle. Diagram shows *scuff marks* along post-impact vector. Speed limit 50 km/h, cyclist's age 7.	A
00175	91	Possible wrong coding, could be KA or even GC. Cycle key vehicle, could have come straight through a Give Way—as implied by movement code—but if so he had veered some 12 m L in crossing the road. Driver said *I was driving along and this kid came out of nowhere. I hit him and he came up over the bonnet and up the windscreen. I braked hard and called the police on my mobile after calling the ambulance.* Investigating officer said *Deceased wearing dark clothing, no bicycle helmet worn (if a safety helmet had been worn this life may have been saved). No lights on bicycle.* (injuries head and internal). Pre-impact direction of cycle not shown but assumed E from movement code and car direction. Point of impact 11.9 m out from kerb (which means the driver had had time to swerve; another 4.5 m and the cyclist would have made it). Carry-on distance not measured and not calculable from measurements given, but more than 17.4 m and probably about 25 m. Speeding seems likely.	T
00032	93	Investigating officer said *unsupervised child playing on tricycle in steep driveway.* Diagram useless.	A

No	Year	Comments	Reason for selection
HA: Right angle crossing, no turns—serious			
01606	94	Cyclist ran red light.	T
12870	94	Cycle key vehicle, report pp 4–5 only. *Little girl came straight out of school gate* (age unknown). Witness said *I saw her ride out onto the roadway and I didn't see her check. She rode between the cars parked in front of the main gates and this van which was driving towards* (town) *hit* (name).	T
22362	94	Driver saw a car some way off, nothing else, *I started to accelerate across the intersection: next thing I know the cyclist was there in front of me. When I hit her she come up onto the bonnet, then through the windscreen. When I stopped she roll back onto the ground. I never saw her at all.* Car crossed road, stopped with rear bumper 17 m past stop line for opposite direction. Cyclist opposite front of car bumper (ie 23 + m from impact) and 4 m to driver's right. Cycle unlit, heavy rain, dark, no street lights, speed limit 100 km/h.	T
06174	95	Wrong coding, should be GC. Cyclist on main road crossed side road then turned R to cross main road on pedestrian crossing, without looking. Hit by car travelling in same direction.	T
14572	95	Cycle key vehicle. Driver slowed at Give Way, then went through junction, hit cyclist on opposite side, *didn't see.*	T
13022	96	Same again—cycle second vehicle this time.	T
22222	96	Cycle key vehicle, not seen by driver at Give Way, in darkness.	A
JA: Crossing vehicle turning right—fatal			
10010	80	Possibly wrong coding, could be HA. Cycle key vehicle, initially on footpath with traffic on his L, continued onto road at junction. Cyclist's age 8.	T
10135	83	Driver no offence. Cycle rode out of driveway, Speed limit 80 km/h, Truck stopped 80 m after impact.	T
00272	85	Wrong coding, should be GC, or possibly MB. Hit by cars in both directions. Cyclist initially riding in same direction as first car, on footpath or hard shoulder.	O
00165	86	Driver did not stop.	T
10188	88	Wrong coding, should be JO (in fact a mirror image LB). Two children playing on cycles in junction of side road and State Highway, riding towards oncoming vehicle, 6 year old turned L into vehicle path.	O
20020	95	Cycle second vehicle, no witnesses, Report page 1 and witness statement only. *Low bright sun, real blinding... Boy on his back with a blanket over him* when driver got back. (how long did he take?).	T
20055	95	Cycle second vehicle, lost control on steep path.	O

JA: Crossing vehicle turning right—serious

No	Year	Comments	Reason for selection
21545	94	Cycle key vehicle, car impact R rear. Driver said, *I let car go past and pulled out. I didn't see her she was behind the ca*r (but on his side of it).	T
22595	94	Wrong cause code. Cycle second vehicle. Driver ran red light, admitted 60 km/h and screen frosting, witnesses said 74–80 km/h; only red light on database. Cyclist protected by traffic lights but *did not check adequately before proceeding at lights* according to database.	O
23459	94	Cycle second vehicle, age 6, rode out onto State Highway from driveway, limit 100 km/h.	O
02342	95	Cycle second vehicle, failed to give way.	T
11328	95	Cycle key vehicle. Driver failed to see both cyclist and following car, which would have had to slow in any case.	T
22632	95	Cycle second vehicle, driver failed to give way, cyclist's age 11.	T
12163	96	Probably wrong cause code. *She just appeared.* Report says *rear* brake faulty (ie makes no difference to stopping power). Investigating officer said, *cyclist very difficult to see*, on database as *inadequate or no headlight*.	T

EA: Hit parked vehicle—fatal

No	Year	Comments	Reason for selection
00127	81	Possibly wrong coding, could be FA or even BE. Cycle third vehicle. Car hit parked stock truck at night, dazzled by oncoming vehicle's lights, not dipped. Cyclist hit in secondary crash or possibly a separate crash. No details on plan or statements.	T
00282	88	Stolen bike, rode into back of angle parked car.	O
10184	90	Rode into broken down car on shoulder, killed by overtaking car? Head injuries.	T
10104	93	Cycle second vehicle. Car hit cyclist standing on shoulder, talking to driver of parked car. Body 29.4 m from impact, offending car 104 m from impact, speed 50? limit 70 km/h. Driver elderly.	A
10116	96	Card not found.	T

EA: Hit parked vehicle—serious

No	Year	Comments	Reason for selection
11135	94	Cycle race pile-up (road partially closed).	O
13193	94	Cycle ran into back of car stopped to drop off passenger.	T
13189	95	Doored.	T
13692	96	Card not found.	T

AA: Pulling out or changing lane to right—fatal

No	Year	Comments	Reason for selection
10081	87	Cyclist coming off 'footpath' hit by truck. Lane 3.8 m, shoulder 0.26 m 2nd card contains photos—reproduction no good.	O
10087	88	Cyclist went under truck after taking L turn slip road. Lane width 10.6 m, impact 7.4 m out from kerb.	T
10089	92	Impact in R lane, 100 km/h dual carriageway.	T

AA: Pulling out or changing lane to right—fatal (continued)

No	Year	Comments	Reason for selection
00129	96	Body 14.7 m plus from impact, bus 57 m +, limit 100 km/h.	T
00182	96	Cycle second vehicle, not seen by driver. Careless driving.	A

AA: Pulling out or changing lane to right—serious

No	Year	Comments	Reason for selection
01182	95	Wrong coding, could be HA, NA or GC. Cyclist probably on footpath. Driver stopped and said *sorry*, left without giving details.	T
23230	95	Wrong coding; should be GC. Cyclist age 6, being followed by his mother, no interview notes for either, driver thought cyclist intended to turn R.	A
05205	96	Wrong coding, should probably be NA. No cyclist movement given, Investigating officer refers to cyclist/pedestrian. Crossing from L in front of motorcyclist.	A
11161	96	Wrong coding, should be AC or FA. Cyclist not seen, aged 11. Impact on edge line, lane width not given. Investigating officer said, (name) *was cycling along in the appropriate part of the road*, which in this case means on the parking lane and bus stop. Witness (passenger in car) says cyclist swerved to R but collision was on white line. Database says *cyclist failed to check behind,* but in that position he should have had no need.	T

GC: Stopped or turning from left side—fatal

No	Year	Comments	Reason for selection
20012	80	Driver inexperienced, cyclist *no idea of road safety*, age 79.	O
10041	81	Probably wrong coding, should be LB. Cycle second vehicle, diagram shows cyclist turned R from L side of road, hit by a vehicle coming in the opposite direction but also shows a third vehicle travelling in the same direction as the cyclist. If this vehicle hit the cyclist the movement code would be correct, but no mention in the text, no details, no witnesses.	T
00072	84	Possibly wrong coding, AA seems more likely. Cycle second vehicle, age 7, possibly startled by overtaking car, hit side of car, perhaps also hit by trailer, M'cycle turning R in front of car may have limited options for driver.	O
10026	86	Driver an investigating officer, *speeding up to execute a 'pursuit speed check'*, charged. Speed 65 in 50 km/h area, skid marks drawn, no measurement.	O
00143	87	Wrong cause code. No dimensions, the investigating officer said, *The driver could not see the cyclist who appeared to have no light*. Light not checked, code is for the front light but the relevant light is the rear.	T

No	Year	Comments	Reason for selection
GC: Stopped or turning from left side—fatal (continued)			
10056	96	Probably wrong coding, should be AA. Cycle key vehicle, no dimensions except 31 m short of junction. If GC code is correct cycle was second vehicle and was turning towards a traffic island. Truck driver claimed to have tried to go around, but no information on position in lane. Claimed speed 85 km/h. No differentiation between impact and final positions. It is possible that final position is shown and the cyclist was intending to turn R earlier and go wrong way up a slip road. Cyclist age 63.	A
GC: Stopped or turning from left side—serious			
01993	94	Cycle second vehicle, turned in front of truck, also hit by oncoming vehicle.	T
11881	94	Cycle key vehicle, driver misjudged cyclist's speed.	A
06607	95	Cyclist turned off footpath, driver claimed he was already driving slowly. Cyclist says *when I was on the road I realised a car was coming... but it was too close for me to get out of the way. The car hit me full side on.* No dimensions.	T
11132	96	No dimensions, car suspiciously far from impact, 100 km/h zone, cyclist age 6.	O
22432	96	Cycle second vehicle, riding to school, elder brother had already crossed, age 10.	A
GB: Side swipe to left side—fatal			
10134	81	Card not found.	A
20023	83	Driver interfered with by passenger.	T
10146	89	Cyclist 7 years, riding to school on 2 lane roundabout. Pinched at entry stop line by a truck driver who had seen the cyclist but was unaware that he had hit anything. Not clear if truck stopped at roundabout.	A
20019	93	Squeezed by truck turning left at traffic signals.	T
00216	94	Squeezed by truck turning left at Give Way.	A
20060	95	Wrong coding, should be EA, cycle second vehicle. Cyclist stopped close to junction, largely on footpath but astride cycle and with rear wheel on the road. Wheel caught by truck and she fell into trailer's path.	O
GB: Side swipe to left side—serious			
05600	95	Wrong cause code. Cycle key vehicle. Driver concerned about cyclist for some 75 m but assumed priority. Driver cut in, not cyclist as coded (357). Offence.	T
21094	95	Cycle key vehicle. Driver swung into service station, cyclist fell off while taking evasive action, no contact.	A
03981	96	Cycle key vehicle. Truck turning into private entrance, driver says cyclist on footpath 200 m before crash but this is not shown on diagram. Downhill, so driver likely to have misjudged cyclist's speed.	A
21506	96	Cycle key vehicle. Truck entering private entrance, cyclist thought turn would be at lights.	A

No	Year	Comments	Reason for selection
KA: Left turn in—fatal			
20024	85	Possibly wrong coding, could be FA. Cycle second vehicle, described as riding out of driveway *and* riding along road: marginal KA/FA. No dimensions. Cyclist's age 6.	T
00282	86	Cycle key vehicle. Truck turned, accelerating on shoulder; not clear if collision with front or side of truck, or even which side.	A
10141	87	Card not found.	A
00197	91	Cycle second vehicle. Cyclist's body 9.8 m from impact, car 21.6 to rear bumper, 50 km/h zone. Investigating officer gave driver factors as, (name) *not wearing a bicycle helmet*. Impact point 1.75 m out from kerb, road 9.2 m wide, no markings.	A
KA: Left turn in—serious			
14222	94	Card not found.	T
06146	95	Possibly wrong coding, could be HA. Investigating officer said *Cyclist failed to look before crossing the road*. Cyclist's age 6.	A
12468	96	Possibly wrong coding, could be HA, or perhaps something else: driver saw rider doing a wheelstand in his headlights. Cyclist's age 18.	A
21912	96	Wrong coding. Cycle hit from behind immediately after L turn by car: should be FA.	T
KB: Right turn in—fatal			
10065	82	Cyclist aged 5 rode out onto divided highway.	A
00254	92	Possibly wrong coding: could be something between HA, KA and BA. Both roads very narrow, corner blind. Not fatal according to TAR, and injuries may not have been very serious (hit side of car, cyclist's injuries should have been determined mainly by cycle speed), but could possibly have died later.	T
10131	95	Wrong coding, should be AC or AO (a mirror-image AF). Three cyclists turned right from driver's right, driver passed t hem on inside. Youngest, age 8, swerved left as car passed. Impact 42 m from junction (so not KB), car stopped 35 m beyond impact point. Speed limit 50 km/h, no mention of speeding or too fast for conditions on database.	O
10095	96	Complex junction, cyclist 2nd vehicle, failed to look.	A
KB: Right turn in—serious			
23122	94	Wrong coding, should be HA. Driver 'a bit lost', ran red light.	A
12569	95	Wrong coding, should be HA. Cycle key vehicle, on footpath, driver leaving private entrance. Both vehicles straight at impact, car intended to cross footpath without turning. Cyclist age 13, *appeared to be travelling at some speed* according to witness.	T

KB: Right turn in—serious (continued)

No	Year	Comments	Reason for selection
01360	96	Probably wrong coding, should be FA. Cyclist turned right at roundabout, hit from behind on roundabout exit, by car going straight through, leaving roundabout on same exit as cyclist. Driver did not stop, charged.	A
01396	96	Wrong coding, should be HA. Same situation as 12569 above.	A

MB: U-turn—fatal

No	Year	Comments	Reason for selection
10153	86	No dimensions, speed limit 100 km/h, cyclist's age 7.	T
10189	89	Probably wrong coding, should be AA. Skid marks 45.5 m, 31.5 m to impact, 100 km/h. Driver's statement under caution, *he sort of turned, then straightened, then made a proper turn this all occurring in a split second.* Moving to centre before turning right looks more likely. Cyclist's age 43.	A
10099	93	Possibly wrong coding: No diagram, statements under caution, events not clear.	A

MB; U-turn—serious

No	Year	Comments	Reason for selection
23287	94	Road width 16 m, 2 lane, cyclist age 13, driver stopped on wrong side of road, 7 m from cyclist.	T
01626	96	Car U-turned.	A
13066	96	Wrong coding, should be HA. Cycle second vehicle. Driver leaving private entrance in fork lift, stopped with forks projecting into road, cyclist rode over them. Cyclist on sealed shoulder about 2 m *left* of cycle track.	A
13092	96	Probably wrong coding, should be HA. Cyclist aged 5, apparently crossing footpath-footpath.	O
22729	96	No dimensions, cyclist turned left, then turned right 20 m clear of junction. Aged 11.	A

AC: Cutting in or changing lane to left—fatal

No	Year	Comments	Reason for selection
10005	82	Swerved inside car waiting to turn right, hit cyclist.	T
00045	89	Wrong coding, should be HA. Cycle second vehicle, came from slip road in wrong direction, working across stationary traffic from R to L, hit in L lane. Car skid marks on drawing but no measurement. Bike/cyclist location after crash unknown. Car brakes defective but no further action, *not at fault in accident.* Faulty brakes not on database.	A
00157	94	Possibly wrong coding, could be AO (in fact a mirror image AF). Cyclist swerved from L side, could have intended to turn R. Truck overtook on L, then cyclist swerved L. Cyclist's age 51.	A
20026	94	Cycle second vehicle. Truck overtaking after lights changed, impact 18 m beyond junction, road narrows from 7.9 m at junction to 6.7 m at impact, cyclist carried 22 m. Following witness saw trailer lift. Two lanes in the same direction.	T

AC: Cutting in or changing lane to left—serious

No	Year	Comments	Reason for selection
23489	94	Cyclist lost control, *wandering or wobbling*. Hands slipped off handlebars. Van behind slowed, car on left didn't.	A
03941	96	Wrong coding, should be GB or GF. Cycle second vehicle, pinched on left at roundabout, car turning left car did not stop.	A
11397	96	Conflicting evidence.	A

AF: Lost control (overtaken vehicle)—fatal

No	Year	Comments	Reason for selection
00279	82	Wind, cyclist aged 5.	T
20086	84	No distance measurements, claimed speed 60–70 in 80 km/h area, total width 8.7 m, marked as 3.3 m lane and 0.9 m other. No interview of 2nd cyclist.	A
10105	86	Cyclist 74, unsteady, swerved into overtaking trailer unit. Road width 9.3 m.	O
20085	89	Cyclist changing gear, hit stone, age 12. Surface problems not on database.	T
20005	93	Cyclist overtook truck on inside, squeezed on *right* hand bend.	A

AF: Lost control (overtaken vehicle) —serious

No	Year	Comments	Reason for selection
13220	94	Cyclist's pedal cleat slipped.	A
23123	94	Cyclist carrying boogie board.	A
12765	95	Cyclist missed pedal.	A
01562	96	Truck driver cut in, no dimensions given, cyclist's age 64.	A

Head-on collisions—fatal

No	Year	Comments	Reason for selection
20079	85	BC Cycle race, cyclist descending hill, ran wide on L bend.	T
00261	90	BA Car went through signalised junction, collided with stationary cyclist waiting to turn R. Driver did not see him at all. Driver: *I was accelerating to the 100 k area, I might have been doing it a bit soon.* No dimensions.	A
10054	90	BE Driver lost control on soft shoulder, crossed road, hit 3 cyclists. Investigating officer said, *speed, inattention*.	O
10050	87	BC Cyclist travelling downhill, failed to take L bend.	T
20100	80	BE Card not found.	A
10151	91	BA Cyclist crossed road diagonally, impact on opposite side, carried 69 m, car continued another 73 m, driver drunk, disqualified.	A
10044	94	BE Cyclist lost control on L bend, skidded on his side into oncoming car. Age 15.	A
10013	90	BC Overtaking car hit two oncoming cyclists. Driver blood alcohol 490. Road narrow (6.0 m between kerbs from personal knowledge; width not in report which has no dimensions).	T
10142	83	AB Driver lost control, hit cyclist on wrong side of road. Driver killed (power pole), cyclist seriously injured. Alcohol involved.	O

No	Year	Comments	Reason for selection
Head-on collisions—fatal (continued)			
00189	84	AB Driver overtaking, hit oncoming cyclist; tried to swerve R to clear cyclist. No dimensions.	A
20096	94	AB Cyclist overtook several traction engines, hit oncoming car. Diagram shows car on wrong side of road but with no explanation. Cyclist's age 9.	A
Head-on collisions—serious			
22622	95	BC Driver failed to keep L, no other information.	T
21569	94	BE Driver lost control on L bend, travelling sideways at impact.	A
11572	95	BC Cyclist came out of side road, hit by trailer of ute coming from cyclist's L. Sight obstructed by parked truck, cyclist's intentions unclear, *no brakes* on cycle.	T
12912	95	BC Bus on one lane bridge, hit by oncoming cyclist travelling too fast.	O
06049	95	BA Cyclist too far to R, just over a rise. Rural road 5.3 m wide, cyclist's age 7.	A
12348	94	BD Narrow winding road, both claimed to be on correct side of road, no impact point established.	A
02969	95	BB Cyclist confused about what to do (?) aged 6. Car speed claimed 80 km/h, skid marks 34 m before impact.	O
02640	94	BC Head-on at apex of L bend (for cyclist). No dimensions, no indication of position or speed.	T
01228	96	AB *Cyclist grossly intoxicated* rode into side of oncoming car's trailer.	A
21655	96	AB Wrong coding, should be AA. Motorcyclist overtaking, cyclist crossed to wrong side of road before impact, due to weight of bags plus looking round?	A

Table C 2: Summary of audited problems

	Ten percent sample (T)		Ten percent sample plus additional sample (T + A)	
	No	%	No	%
Total	73	100 %	127	100 %
Movement code wrong	7	10 %	15	12 %
Movement code possibly or probably wrong	7	10 %	14	11 %
Cause code wrong	9	12 %	10	8 %
Cause code possibly or probably wrong	2	3 %	2	2 %
Card not found	5	7 %	8	6 %

Appendix D:
Audit of junction improvements

Thanks to Wellington City Council for supply of drawings and permission to publish details.

Note that the intention here is to show changes in safety, regardless of safety levels before the alterations were made. However, suggestions are intended to improve on the original where possible.

Scores are:

1	Definitely worse for cyclists
2	Probably worse for cyclists
3	No change
4	Probably better for cyclists
5	Definitely better for cyclists

Scores for main routes are arbitrarily doubled to reflect the more intensive use.

Table D.1: Junction 1

T-junction with traffic island on minor road joining busy suburban road (Burma Rd and Fraser Avenue: North = Burma Rd to Johnsonville)

Traffic islands have been placed on the leg of the T.

Cyclist's Direction	Comments	Score
S-N	(Main route) No change	6
S-E	Pinch point on exit but central island slows turning traffic	4
N-S	(Main route) Traffic entering from left slowed	10
N-E	Pinch point on exit but central island slows turning traffic	4
E-S	Pinch point on exit, overtaking traffic slowed	2
E-N	Traffic islands slow turning traffic and provide protection	5
	Average for junction	3.9

The junction has been made safer for cyclists.

Table D.2: Junction 2

Roundabout with drive-over collar, on busy suburban road (Moorefield Road and Haumia St: North = Moorefield Rd)

A crossroads converted to a roundabout. The core is 5 m diameter, the collar 9 m. The collar, intended to provide overrun space for large vehicles at low speeds is much too low; I was able to drive over it at speed in a small car, without discomfort. Widths are also too great, at 6.6 to 8.3 m. The result is that the roundabout provides very little deflection and motor vehicle speeds are too high.

Cyclist's Direction	Comments	Score
S-W	Entry too wide	2
S-N	(Main route)	2
S-E	Some slowing of opposing traffic	1
W-N	Entry width good, radius too large	3
W-E	Some slowing of cross traffic	1
W-S	Some slowing of cross traffic	1
N-E	Entry width good	3
N-S	(Main route)	2
N-W	Some slowing of cross traffic	1
E-S	Entry too wide	3
E-W	Some slowing of cross traffic	1
E-N	Some slowing of cross traffic	1
Average for junction		1.5

The junction has been made substantially more dangerous for cyclists. Suggested improvements are:

- Install traffic signals with advanced stop lines and reservoirs for cyclists (preferred).
- Redesign the roundabout to cycle-friendly standards.

Table D.3: Junction 3

Mini-roundabout with drive-over core on busy suburban road (Box Hill and Cockayne Rd, North = Box Hill)

A Y-junction has been converted to a roundabout. The whole core of the roundabout is too low, giving insufficient deflection; I was able to drive over it at speed in a small car.

Cyclist's Direction	Comments	Score
S-W	Approach too wide	2
S-N	(right turn) Some slowing of traffic from right but almost none from left	1
W-N	(Main route) Approach too wide, traffic cutting corner	2
W-S	Positioning difficult, fast approaching traffic	1
N-S	Approach too wide	2
N-W	(Main route) Positioning difficult	2
Average for junction		1.3

The junction has been made substantially more dangerous for cyclists. Suggested improvements are:

- Install traffic signals with advanced stop lines and reservoirs for cyclists (preferred).
- Redesign the roundabout to cycle-friendly standards.

Table D.4: Junction 4

T-junction with traffic signals and a left turn slip road on busy urban streets (Riddiford St and Constable St, North = Riddiford Rd)

An existing signalised junction has been improved, largely with pedestrians in mind. It is on two bus routes.

Cyclist's Direction	Comments	Score
S-N	(Main route) Kerb build-out does not extend beyond car parking lane	6
S-E	No change	3
N-E	(Main route) Little change	6
N-S	(Main route) Slip road little changed, straight-ahead lane width 3.5 m, no holding area for cyclists going straight ahead	2
E-S	Kerb built out, bollards form a pinch	1
E-N	(Main route) No change	6
Average for junction		2.0

The junction has been made substantially more dangerous for cyclists, and opportunities for substantial improvements have been missed.

Suggestions for improvements are:

- Remove or set back the new bollards on the SE corner, which could trap a cyclist against a turning truck (movement code GF).
- Widen the N-S lane to 4.2 m and provide a cycle lane on the approach, across the N-E free turn.
- Widen the left lanes on the southern and eastern approaches to 4.2 m, if possible.
- Provide advanced stop lines with reservoirs on all approaches.

Table D.5: Junction 5

T-junction on minor road, busy urban street (Riddiford St and Wilson St, North = Riddiford St)

The entrance to a minor one-way street (running away from the main road) has been traffic calmed. The main road is a busy shopping streets used by several bus routes.

Cyclist's Direction	Comments	Score
S-N	(Main route) Build-out replaces bus stop moved north, width between kerbs 4.6 m	6
S-E	Traffic island provides shelter while waiting to turn, uneven surface in minor road entrance	4
N-E	Turning traffic slowed	3
N-S	(Main route) No change	6
Average for junction		3.2

The junction has been made slightly safer for cyclists.

Table D.6: Junction 6

Y-junction with traffic signals, busy urban streets (Riddiford and Rintoul Sts, North = Riddiford St)

An existing signalised junction has been improved, largely with pedestrians in mind. It is on several bus routes. Three directions are 'main' and a fourth very minor, so the minor leg has been ignored and no weighting has been applied.

Cyclist's Direction	Comments	Score
S-W	No change	3
S-N	No change on entry, exit 2 x 2.8 m lanes. This is nominally a safe arrangement, but lane markings are over a short distance, on a bus route and are usually ignored	2
W-N	No change on entry, build-out in junction forms a pinch point, parking within the junction create possible problems	1
W-S	No change	3
N-S	New kerb line forms pinch point immediately behind stop line, lane width 3.2 m	1
N-W	Lane narrowed to 3.1 m	3
Average for junction		2.2

The junction has been made more dangerous for cyclists, and opportunities for substantial improvements have been missed. Suggested improvements are:

- Reduce the northbound exit to one motor traffic lane and a cycle lane.
- Widen the western approach lane to 4.2 m if possible.
- Eliminate the parking bays within the junction (which are an afterthought: they are not on the plans).
- Widen the kerb lane on the northern and southern approaches to 4.2 m, and provide advanced stop lines and reservoirs for cycles.
- Reduce the width of the pedestrian build-out on the northern approach, and increase its length.

Table D.7: Junction 7

New pedestrian crossing in small suburban shopping centre (Upland Rd, East = to City)

An unsatisfactory pedestrians crossing in a suburban shopping centre has been improved, with a central island and offset crossings. It is on a bus route.

Cyclist's Direction	Comments	Score
E-W	Build-out for pedestrian crossing, 4.2 m on entry, 4.1 m on exit, on right hand curve (radius about 40 m)	2
S-N	Build-out for pedestrian crossing 4.2 m, on left hand curve, with a bus stop immediately before the crossing.	3
Average for junction		2.5

The junction has been made slightly more dangerous for cyclists. Suggested improvements are:

- Move the eastbound bus stop to the east of the crossing **or** use a bus berth (built-out kerb, obstructing flow when a bus is at the stop).
- Widen the crossing lanes to, say, 4.5 m, because of the curve.

Table D.8: Junction 8

T-junction with moderate turning traffic at a suburban shopping centre (Upland Rd and Plunket St, North = T leg)

One corner of the junction has been built out, for pedestrians.

Cyclist's Direction	Comments	Score
W-E	(Main route) No change	6
W-S	No change	3
S-E	No change	3
S-W	Slightly improved sight lines	4
E-W	(Main route) Poor flow of stop lines and parking lane on plan, corrected on site	8
E-S	Reduced kerb radius slows turning traffic but increases pinch effect	2
Average for junction		3.3

The junction has been made slightly safer for cyclists.

Table D 9: Junction 9

Busy crossroads with traffic signals in CBD (Cambridge/Kent Terraces and Courtenay Place, North = Cambridge Terrace)

A major junction has been altered as part of a shopping area improvement. The junction remains under traffic signal control, with heavy turning bus traffic.

Cyclist's Direction	Comments	Score
S-W	New slip road allows higher speeds for turning traffic	2
S-N	(Main route) Straight-ahead lane width 3.6 m, no reservoir area for cycles, entry slip road on junction exit	2
S-E	No change	3
W-N	Slip road	1
W-E	No cycle lane across slip road	2
W-S	Lane width 4.4 m, right turn from left lane permitted	4
N-E	Lane width 4.0 m, no other change	3
N-S	(Main route) Lane width 4.0 m, no other change	6
N-W	No change	3
E-S	No change	3
E-W	Dog-leg removed: now straight through	4
E-N	No change	3
Average for junction		2.6

The junction has been made more dangerous for cyclists and opportunities for substantial improvements have been missed. Suggested improvements are:

- Widen the left hand lanes to 4.2 m wherever possible.
- Provide a cycle lane at the crossing of the S-W and E-N slip roads (the angle parking also needs a cycle lane outside it).
- Provide advanced stop lines and reservoirs on the northbound, southbound and eastbound approaches.

Appendix E: Proportion of urban trips on traffic calmed streets

An estimate is made of the proportion of all trips that would be on 30 km/h streets if Wellington were fully traffic calmed, for use in estimating the cost of traffic delays in the event of full traffic calming being introduced. The method used isgoven below.

- Select every fourth 1.0 kilometre grid square on the 1:20 000 plan of Wellington (Infomap 271-37, 1988 edition). Ignore selected grid squares which are judged to be less than 50 % covered by housing.
- Locate the road junction closest to the centre of each selected square.
- Measure the distance by road from the selected junction to the nearest 'reasonably substantial' shopping centre (taken as Johnsonville, Crofton Downs, Karori Mall, Cable Street, Riddiford Street or Miramar Avenue). Other similar shopping centres are ignored because they do not happen to be closest to a selected junction.
- Measure the distance by road to the CBD (taken as Harris Street).
- Estimate the proportion of each journey made on local streets (coloured white on the plan: assumed to be traffic calmed) or on main routes (yellow on the plan) but judged to need traffic calming because of lack of width, shopping centres and/or lack of visibility on bends. The streets so judged include Stewart Drive; Johnsonville Road; Cashmere Avenue and Onslow Road (north of Homebush Rd); Wadestown, Lennel, Grosvenor and Grant Roads; Curtis Street; Upland Road; Glasgow Street; Kelburn Parade and Salamanca Road; The Terrace (south of Salamanca Road); Wallace Street; Adelaide Road (John Street to Duppa Street); and Riddiford, Rintoul and Luxford Streets. This list is not complete because not every street needed to be considered for this study.
- Estimate the proportion of each journey made on roads marked on the plan as through routes or main urban routes (brown or yellow on plan, assumed to be not traffic calmed) and not listed above.

Measurements are made using a map measurer, in units of 508 m (One inch at 1: 20 000 scale)

The result may be an under-estimate because of business traffic in the traffic calmed central area, but may also be an over-estimate because some streets assigned here as traffic calmed might retain a 50 km/h speed limit.

In the short term it is clearly a gross over-estimate, with no political support for traffic calming on such a scale.

Average distance on traffic calmed streets
= (30.5 + 33.0) / (46.5 + 148.0) = 33 %

Table E 1: Distances on traffic calmed and non-traffic calmed streets

	Shops		CBD	
	Traffic calmed distance (arbitrary units)	Total distance (arbitrary units)	Traffic calmed distance (arbitrary units)	Total distance (arbitrary units)
Mark Av / Guadaloupe Cres (west)	5.0	6.0	5.5	23.5
End of Bloomsbury St (Newlands)	4.0	5.0	1.0	21.0
Lyndfield La / Miles Cres (west) (N'lands)	2.5	4.0	1.0	18.5
Jubilee Rd / Amritsar St	2.5	6.5	2.5	13.5
Hanover St / Wadestown Rd	1.0	3.5	3.0	7.0
Pembroke Rd / Abarmarle Rd	1.5	4.0	5.0	9.0
Dasent St / Beauchamp St (Karori)	1.0	1.0	6.5	12.0
Salisbury Tce / Wright St (Mt Cook)	2.5	2.5	1.0	4.0
Abel Smith St / Cuba St (Te Aro)	0.5	3.0	0.5	2.5
Akatea St / Adelaide Rd (Berhampore)	3.0	3.0	3.0	8.5
Kedah St / Miro St, (Miramar)	2.0	2.0	1.0	12.5
Sidlaw St / Ahuriri St (Strathmore Pk)	5.0	6.0	3.0	16.0
Totals	30.5	46.5	33.0	148.0

Appendix F: Street and parking capacity increase with cycle use

Traffic capacity

Suppose a traffic lane has a 'standard' streaming capacity of 1670 vehicles/h, as given by Underwood (1995) for saturation flow, average conditions and mixed turning and through traffic. Assume 1.44 persons per vehicle (implied NZ average in MoT, 1992). Using Underwood's motor vehicle capacity/road width equations, a table of lane widths and person-carrying capacities can be prepared. See Table F.1.

CROW (1993) gives capacities of 3300 cycles/h for a streaming lane 1.0 m wide and 4700 /h for 1.8 m wide. Minimum widths are given as 1.5 m for cycling 2 abreast, 2.5 m for cycling 3 abreast etc. The capacity/width curve is in fact a 'fuzzy' step function: two cyclists cannot ride side by side in 1.0 m width, can just ride side by side in 1.5 m (probably with some delay) and can ride without delay in 1.8 m. The curve can be conservatively plotted as tangential to the steps, assuming one person per cycle:

Capacity = [(Width - 0.8 m) x 3300] +1000 cycles/hr

This gives cycle capacities of:

1660 per hour on 1.0 m width
3300 per hour on 1.5 m width
4300 per hour on 1.8 m width
4960 per hour on 2.0 m width

This is clearly conservative in some cases: Homburger et al (1996) give capacity as up to 2600 cycles/hr.m width, and describe 1300–1960 cycles/hr.m as level of service 'C'. However, they also give the speed as 15–17 km/h (and down to 10–13 km/h at capacity), so perhaps some conservatism is appropriate.

In the Netherlands a cycle is taken as using 30% of the road space of a car[17] (ie pcu value = 0.3), which is reasonably consistent with Table F.1.

[17] Information from Walter Hook, Institute for Transportation and Development Policy <mobility@igc.apc.org>, 5/1/98 (Sustrans news group on internet)

Parking capacity

Austroads 14 recommend a 1200 mm spacing for cycle stands, suggesting that 10 cycles can be parked in the space needed for one 6.0 m car parking bay, with two cycles on each stand. Sustrans (1997) allow 1000 mm, or 12 cycles per bay. Allowing 1.44 persons per car gives a cycle parking requirement about 7–8 times smaller than for cars.

Higher cycle parking densities can be achieved with mechanised systems, by hanging cycles, or by stacking them bike against bike, but this last arrangement tends to be first in, last out.

Table F 1: Passenger carrying capacity with and without cycle facilities

Available width (m)			Capacity (persons/hr)			Capacity increase with cycle facility
Total	Traffic	Cycles	Traffic	Cycles	Total	
3.0	3.0	–	2400	–	2400	
3.0	–	3.0*	–	8200	8200	3.4
3.5	3.5	–	2400	–	2400	
3.5	–	3.5*	–	9900	9900	4.1
4.0	4.0	–	2500	–	2500	
4.0	–	4.0*	–	11500	11500	4.6
4.5	4.5	–	2600	–	2600	
4.5	3.0	1.5	2400	3300	5300	2.0
5.0	5.0	–	2600	–	2600	
5.0	3.5	1.5	2400	3300	5700	2.2
5.0	3.0	1.5†	2400	3300	5700	2.2
5.0	3.0	2.0	2400	5000	7000	2.7
5.5	5.5	–	2600	–	2600	
5.5	3.5	1.5†	2400	3300	5700	2.2
5.5	3.0	2.0†	2400	5000	7000	2.7
5.5	3.0	2.5	2400	6600	8600	3.3
7.0	2 x 3.5	–	4800	–	4800	
7.0	3.0 + 2.5	1.5	4600	3300	7900	1.6
8.0	2 x 4.0	–	5000	–	5000	
8.0	2 x 3.0	2.0	4800	5000	9800	2.0
8.0	2 x 3.25	1.5	4800	3300	8100	1.6
8.0	2 x 3.0	1.5†	4800	3300	8100	1.6

* Not recommended without physical separation
† Additional width used to separate cycle and motor traffic

Appendix G: LTSA Movement Codes

The diagram at right is the coding sheet in use in March 2008. It contains several changes from the movement codes in use when this study was originally made. Fortunately, the only changes to codes selected for special study (Table 3.3) are two useful subdivisions.

- EA (hit parked vehicle) is now separated from EE (hit door).
- MB and MC (both U-turn) now distinguish the direction of the U-turn.

Table G1 shows the differences between the current movement codes and those used in this study.

It is regrettable that crowding is still (2008) not recognised as a specific problem (recommendation 13 in Appendix A). The result is that crowding crashes remain in the *dunkelziffer* zone (paragraph 4.20) and another decade of data has been lost. However, it is pleasing to see that code EA has been split.

Table G1: Differences between current movement codes and codes used in this study

A	Overtaking and lane change	**AA**	**AB**	**AC**	AD	AE	**AF**	AG	AO
B	Head on	**BA**	**BB**	**BC**	**BD**	**BE**	**N**		BO
C	Lost control or off road (straight roads)	CA	CB	CC					CO
D	Cornering	DA	DB	DC					DO
E	Collision with obstruction	**EA**	EB	EC	ED	**N**			EO
F	Rear end	**FA**	FB	FC	FD	FE	FF		FO
G	Turning versus same direction	GA	**GB**	**GC**	GD	GE	(GF)		GO
H	Crossing (no turns)	**HA**	**X**	**X**					HO
J	Crossing (vehicle turning)	**JA**	**X**	JC	**X**	**X**			JO
K	Merging	**KA**	**KB**	KC					KO
L	Right turn against	LA	**LB**						LO
M	Manoeuvring	MA	(MB)	(MC)	MD	ME	N	(MG)	MO
N	Pedestrians crossing road	NA	NB	NC	ND	NE	NF	NG	NO
P	Pedestrians other	PA	PB	BC	BD	PE	PF		
Q	Miscellaneous	QA	QB	QC	QD	QE	QF	QG	QO

ZZ Unchanged
ZZ Unchanged (code selected for analysis in this study)
(ZZ) See further notes below
N New code
X Old code no longer used

GF Footnote is new
MB Now U-turn into path of key vehicle (was U-turn either way)
MC Now U-turn out of path of key vehicle (was reversing along road)
MG Replaces old MC

Land Transport NZ
Ikiiki Whenua Aotearoa

VEHICLE MOVEMENT CODING SHEET

For use with crash data from **CAS** (Version 2.4 February 2005)

	TYPE	A	B	C	D	E	F	G	O
A	OVERTAKING AND LANE CHANGE	PULLING OUT OR CHANGING LANE TO RIGHT	HEAD ON	CUTTING IN OR CHANGING LANE TO LEFT	LOST CONTROL (OVERTAKING VEHICLE)	SIDE ROAD	LOST CONTROL (OVERTAKEN VEHICLE)	WEAVING IN HEAVY TRAFFIC	OTHER
B	HEAD ON	ON STRAIGHT	CUTTING CORNER	SWINGING WIDE	* BOTH OR UNKNOWN	LOST CONTROL ON STRAIGHT	* LOST CONTROL ON CURVE		OTHER
C	LOST CONTROL OR OFF ROAD (STRAIGHT ROADS)	OUT OF CONTROL ON ROADWAY	OFF ROADWAY TO LEFT	OFF ROADWAY TO RIGHT					OTHER
D	CORNERING	LOST CONTROL TURNING RIGHT	LOST CONTROL TURNING LEFT	MISSED INTERSECTION OR END OF ROAD					OTHER
E	COLLISION WITH OBSTRUCTION	PARKED VEHICLE	CRASH OR BROKEN DOWN	NON VEHICULAR OBSTRUCTIONS (INCLUDING ANIMALS)	WORKMANS VEHICLE	OPENING DOOR			OTHER
F	REAR END	SLOW VEHICLE	CROSS TRAFFIC	PEDESTRIAN	QUEUE	SIGNALS	OTHER		OTHER
G	TURNING VERSUS SAME DIRECTION	REAR OF LEFT TURNING VEHICLE	LEFT TURN SIDE SIDE SWIPE	STOPPED OR TURNING FROM LEFT SIDE	NEAR CENTRE LINE	OVERTAKING VEHICLE	* TWO TURNING		OTHER
H	CROSSING (NO TURNS)	RIGHT ANGLE (70° TO 110°)							OTHER
J	CROSSING (VEHICLE TURNING)	RIGHT TURN RIGHT SIDE	OBSOLETE	TWO TURNING					OTHER
K	MERGING	LEFT TURN IN	RIGHT TURN IN	TWO TURNING					OTHER
L	RIGHT TURN AGAINST	STOPPED WAITING TO TURN	MAKING TURN						OTHER
M	MANOEUVRING	PARKING OR LEAVING	"U" TURN	"U" TURN	DRIVEWAY MANOEUVRE	PARKING OPPOSITE	ENTERING OR LEAVING	REVERSING ALONG ROAD	OTHER
N	PEDESTRIANS CROSSING ROAD	LEFT SIDE	RIGHT SIDE	LEFT TURN LEFT SIDE	RIGHT TURN RIGHT SIDE	LEFT TURN RIGHT SIDE	RIGHT TURN LEFT SIDE	MANOEUVRING VEHICLE	OTHER
P	PEDESTRIANS OTHER	WALKING WITH TRAFFIC	WALKING FACING TRAFFIC	WALKING ON FOOTPATH	CHILD PLAYING (TRICYCLE)	ATTENDING TO VEHICLE	ENTERING OR LEAVING VEHICLE		OTHER
Q	MISCELLANEOUS	FELL WHILE BOARDING OR ALIGHTING	FELL FROM MOVING VEHICLE	TRAIN	PARKED VEHICLE RAN AWAY	EQUESTRIAN	FELL INSIDE VEHICLE	TRAILER OR LOAD	OTHER

* = Movement applies for left and right hand bends, curves or turns