Peer Reviewed Papers

Crash prediction models and the factors that influence cycle safety

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Abstract

An increase in cycling in our cities and towns can bring many benefits, including healthier people, reduced emissions from motor vehicles, reduced parking demand and less traffic congestion. A major deterrent to the taking up of cycling, however, is the increased risk of having a crash compared with travelling as a driver or passenger in a motor vehicle. This paper presents research findings from three studies focused on understanding and reducing the risk of on-road cycle crashes.

The first study focuses on the relationship between motor vehicle flow, cycle flow and crashes. The key finding is that as cycle volumes increase, the risk per individual cyclist reduces – the 'safety in numbers' effect. The second study focuses on the factors and interventions that influence cycle safety, other than cycle flows. This study involved the development of crash models for mid-block road links in Christchurch, New Zealand, and looks at factors such as provision of cycle lanes, kerbside parking demand, number of access-ways, speed of traffic and presence of a flush (painted) median. The third study, on the effectiveness of cycle facilities at intersections, looks at the relationship between the various cycle facilities installed at traffic signals and crashes. Data on cycle facilities, general road layout (e.g., number of traffic lanes and intersection depth), crash occurrence and traffic flows have been collected at 200 traffic signals in Auckland, Christchurch, Dunedin and Adelaide.

Keywords

(Bi)cycle facilities, Crash prediction models, Safety in numbers, Safety performance functions

Introduction

Although there are many guidance documents available for the design of cycle facilities, there is limited research on the effectiveness of different types of treatments, particularly at intersections. The existing primary source of guidance for cycle planning in Australia and New Zealand is the *Austroads Guideline for Traffic Engineering Practice (GTEP) Part 14*. This guide provides information on the types of facilities that are available, but provides little or no research on the safety benefits of each type of facility.

This paper presents recent research on the safety of cyclists on New Zealand roads. It examines cycle safety on roads with and without cycle facilities and the impact on cycle safety of various road features, including flush (painted) medians and kerbside parking. Finally, it previews research that is in progress to look in more detail at the safety impact of cycle facilities at intersections across New Zealand and Australia.

A number of studies have been conducted to investigate the safety benefits of cycle facilities. Only a limited number of studies consider crash occurrence directly, through before-and-after studies and crash prediction models. Other studies used traffic conflict techniques and risk indices. It is acknowledged by most that the risk of being involved in a crash while cycling is typically higher than while travelling in a motor vehicle, and the key concern is the severity of injuries to cyclists. Research by Jacobsen [1], however, demonstrates that there is a 'safety in numbers' effect for cyclists.

Coates [2] performed a before-and-after analysis of crashes at locations where cycle lanes had been marked at mid-block locations and concluded that providing cycle lanes at mid-block locations negatively impacted on crashes at intersections with a very small increase in the number of crashes. This conclusion did not, however, take into account increasing cycle volumes.

Elvik and Vaa [3] found that an advanced stop bar for cycle lanes at intersections leads to a 27% decrease for cycle injury crashes and a 40% reduction in total crashes. In addition, they found that adding cycle lanes through a signalised intersection reduces cycle crashes by 12%, but increases overall crashes by

14%. Construction of grade-separated crossings leads to a major decrease of 30% in total crashes. A summary of further research on this topic can be found in Turner et al. [4]

Crash prediction models

There is a large body of crash prediction modelling (also called accident prediction modelling or the development of safety performance functions) internationally. Crash prediction models are mathematical models that relate crashes to traffic volume and other road layout and operational features. The majority of this research is focused on the relationship between 'motor vehicle only' crashes (or total crashes) and traffic flows and other predictor variables. There are relatively few studies focused on 'cycle with motor vehicle' crashes, relating these to the volumes of vehicles and cyclists that use an intersection or travel down a route. The development of models for cyclists is hindered by the lack of information on cycle volumes and the location and implementation of cycle facilities.

Crash prediction models are cross-sectional regression models. With crashes being discrete events and typically following a Poisson or negative binomial distribution, traditional regression analysis methods, such as linear regression, are not suitable. The models used in crash prediction are developed using generalised linear modelling methods. Generalised linear models were first introduced to road accident studies by Maycock and Hall [5], and extensively developed in Hauer et al. [6] These models were further developed and fitted using crash data and traffic counts in the New Zealand context for 'motor vehicle only' crashes by Turner [7].

The aim of this modelling exercise is to develop relationships between the mean number of crashes (as the response variable), and traffic and cycle flows, as well as non-flow predictor variables. Typically the models take the multiplicative form,

$$A = b_0 x_1^{b_1} \ldots x_i^{bi} e^{b_{i+1}x_{i+1}} \ldots e^{b_n x_n}$$

where A is the fitted annual mean number of crashes/accidents, the x_1 to x_i are measurement variables such as average daily flows of vehicles, pedestrians or cyclists, the x_{i+1} to x_n are categorical variables recording the presence, for example, of a cycle installation, and the $b_1,\ldots,b_n$ are the model coefficients.

Application of crash prediction models

Crash prediction models can indicate how various road layout and operational factors influence the occurrence of crashes and, in this situation, crashes involving cyclists. The models enable us to quantify the effect of various factors, rather than speculate on the level of influence. This is important if we want to understand what factors have the most significant effect on road safety and need to be addressed through interventions.

In terms of cycle safety it is important to determine the key factors that influence the occurrence of particular crash types, so that their effects can be minimised. Such factors include motor vehicle volumes and speeds, and road cross-section. It is also important to understand the safety implications of safety interventions, such as wider kerbside lanes, removal of parking and provision of cycle facilities on road links and at intersections. The goal is to reduce the crash risk for cyclists to levels that are as close as possible to those of motor vehicle drivers and passengers. Traffic engineers and other professionals can use the results of such research to make decisions and to justify those decisions using evidence of the expected crash savings.

NZ studies on crash prediction models for cyclists

Research by Turner [7, 8] identified that outside the top three or four major 'motor vehicle only' injury crash types, the next few significant crash types often involved pedestrians or cyclists (the active modes). The proportion of 'active mode' crashes is, however, quite variable, depending on the volume of cyclists and pedestrians using the intersection or travelling along or crossing the mid-block route. Hence traffic signals have a higher proportion of pedestrian crashes than roundabouts, mainly due to most roundabouts being located in areas with low pedestrian demand. Across New Zealand it was found that cycle crashes were a lot higher at roundabouts in Christchurch than at roundabouts in Auckland, because of the much higher number of cyclists in the former.

Since 2000 three studies have been undertaken on crash models for cycle versus motor vehicle crashes. The first study by Turner et al. [9] examined the relationship between crashes and cycle and motor vehicle volumes at traffic signals, roundabouts and mid-block sections. It also looked at crashes involving pedestrians at these three site types. The second study by Turner et al. [4] looked at the effect on cycle safety of a number of road features along mid-block sections, including parking, cycle lanes and painted (flush) medians. The third study, which is still in progress, looks at the safety impact on cyclists of various cycle facilities at traffic signals.

Data collection

This research has made use of three sample sets. We have referred to these as Study 1, Study 2 and Study 3.

Sample sets

Study 1 (Turner et al. [10]) focused on the relationship between cycle versus motor vehicle injury crashes, and cycle and motor vehicle volumes. This study included three site types: roundabouts, traffic signals and mid-block sections. The majority of the data was collected from Christchurch, with extra data at intersections from Palmerston North and at mid-blocks from Hamilton. Sites were selected based on the availability of manual turning motor vehicle counts in each city. Table 1 shows the number of sites of each type collected from each city.

Table 1. Number of sites in each sample set (Study 1)

City	Traffic signals	Roundabouts	Mid-blocks
Christchurch	97	42	50
Hamilton	0	0	13
Palmerston North	20	3	0
Total	117	45	63

Study 2 (Turner et al. [11]) focused on mid-block locations and the effect on safety of various road features, primarily cross-section factors (e.g., kerbside lane width, cycle lanes, painted medians and parking provision). This study included a sample of 97 mid-block urban sections from Christchurch in New Zealand. This sample included road sections with and without cycle lanes; approximately half had cycle lanes. Almost all routes that had had a cycle lane for at least five years were included in the sample. Figure 1 shows the distribution of lengths of the mid-block urban sections included in the sample. Road sections started and finished 50m back from a major intersection, such as those with traffic signals or a roundabout.

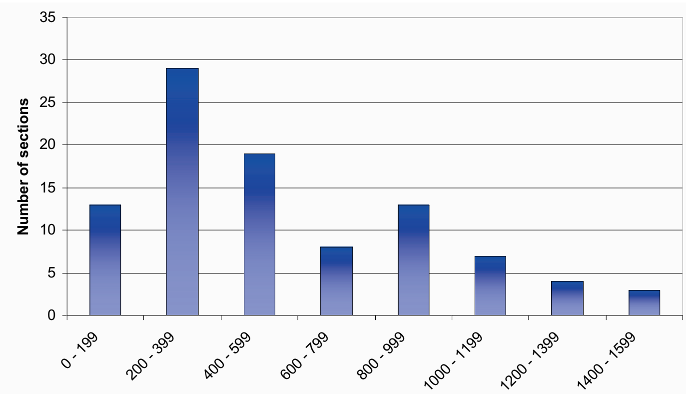

Figure 1. Mid-block sections by section length (Study 2)

Study 3 looks at the impact that cycle facilities can have on cycle crashes at traffic signals. A total of 80 sites and 310 approaches are included from three- and four-arm traffic signals in Christchurch. A further 99 sites are to be collected from Adelaide. (See Table 2.) All traffic signals in each city that have had cycle lanes for at least five years, and for which cycle counts were available, were selected for this study. These Adelaide sites have not been included in the preliminary analysis provided in this paper.

Table 2. Number of sites in each sample set (Study 3)

Location			3-arm site	4-arm site	Total
Adelaide	Cycle treatment	No	1	6	7
		Yes[a]	12	80	92
	Total		13	86	99
Christchurch	Cycle treatment	No	3	10	13
		Yes[a]	7	60	67
	Total		10	70	80

[a]At least one cycle treatment type was installed on at least one arm of the intersection. Some intersections only have partial cycle treatment.

Crash data for New Zealand sites (those reported to police) were obtained from the New Zealand Crash Analysis System (CAS), a national crash database covering all New Zealand roads.

Traffic and cycle volumes

Motor vehicle and cycle count data was collected for the various studies from Christchurch, Hamilton and Palmerston North in New Zealand and Adelaide in Australia. These cities were chosen because of the significant numbers of cyclists and the availability of manual cycle counts. For Studies 2 and 3, the focus was on Christchurch and Adelaide due to the numerous cycle facilities that have been installed at intersections and along roads in these cities.

Motor vehicle and cycle counts were obtained in Christchurch from the Christchurch City Council (CCC). The CCC have had a long-term program (in many cases annual) to collect manual turning movement counts (motor vehicle and cyclist) at intersections in the city. They also have a special program for collecting cycle only counts at intersections at less frequent intervals. Where these separate cycle counts are available, they have been used for Christchurch sites, as they have been found to be more accurate (surveyors sometimes miss cyclists when also counting motor vehicles). The other three cities (Adelaide, Hamilton and Palmerston North) also collect manual turning counts at intersections at various intervals – from annually to every three or four years.

The manual turning movement counts were collected (for Studies 1 and 3) on weekdays and during the school term. Motor vehicle counts were typically collected for a one-hour period during the morning (7:00am – 9:00am) and evening (4:00pm – 6:00pm) peak periods. Cycle counts were collected for a one-hour period (and 1.5 hours in some cases) over the morning peak (7:30am to 9:00am) and the evening peak (4:15pm to 5:45pm). The evening peak for some of the sites, however, was observed to be between 2:30pm and 4:00pm, coinciding with the school afternoon peak.

The CCC also collects manual and automated mid-block link counts (motor-vehicles and cyclists). These mid-block counts were used for the mid-block crash models developed in Study 2. Continuous cycle count data at some of the automated count sites was also collected. This was used to study daily and weekly trends in cycle flows.

Other predictor variables

Data on parking utilisation, presence and width of flush medians, and mid-block speed was collected for Study 2 from field observations and aerial photos. No non-flow predictor variables were collected for Study 1.

Geometry data was collected for the intersection in Study 3, including the number of traffic lanes, traffic and cycle lane widths, lengths of right turn bays and intersection depth. This data was collected using GIS tools and scaled aerial photos. Lane layouts were coded and categorised into 47 types according to the number of turning lanes and the presence of shared turning lanes. Lane layout types and corresponding codes used are depicted in Appendix A. Also in Study 3, the presence and type of cycle treatments on each approach of the selected intersections were also noted. Cycle treatments were classified according to type, i.e., whether transition, approach, through or departure. Appendix B depicts each of the treatment classifications used in the study

Data analysis

The major crash types for each form of intersection control and for mid-blocks are presented in this section. Crash prediction models were then developed for these major crash types. The initial data analysis also involved converting raw (counted) traffic and cycle volumes data to representative 24-hour turning movement counts for each intersection.

Cycle crash analysis

Figure 2 shows the proportion of cycle crashes that occurred at different locations in the road network (traffic signals, roundabouts, etc.) in the period 1999 to 2003 across New Zealand (from Study 1). Figure 2 shows that 42% of crashes occurred on mid-block sections (including driveway crashes) and a further 16% occurred at traffic signals (7%) and roundabouts (9%). The remaining crashes (some 42%) occurred at other intersections, the majority of which have priority control.

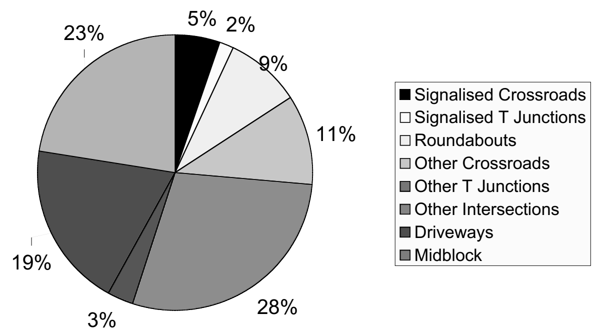

Figure 2. Cycle crashes by sites type (1999 to 2003)

Figure 3 shows the types of cycle crashes that occurred at the different site types in Study 1 for the same five-year period. Figure 3 shows that 'right turn against' (LB – refer to Appendix C) and 'right angle' (HA and JA) crashes are the major types. These crashes involve a cyclist and motorist colliding in the intersection. The majority of the remaining crashes occur on the approach to the intersection. The major crash type at roundabouts involved a motorist entering the roundabout and colliding with a cyclist (consisting of the majority of the observed HA, LB, KA and KB crashes).

Certain crash types were combined for the purpose of modelling, as there were insufficient observed crashes to develop relationships for every crash type. A significant proportion of cycle crashes occur where the cyclist collides with a stationary vehicle or collides with a motor vehicle travelling in the same direction. Crash types A, E, F and G were combined to create a crash model for 'same direction' crashes. Intersecting crashes were represented by models built for HA type crashes, while separate 'right turn against' crash models were built for LB type crashes.

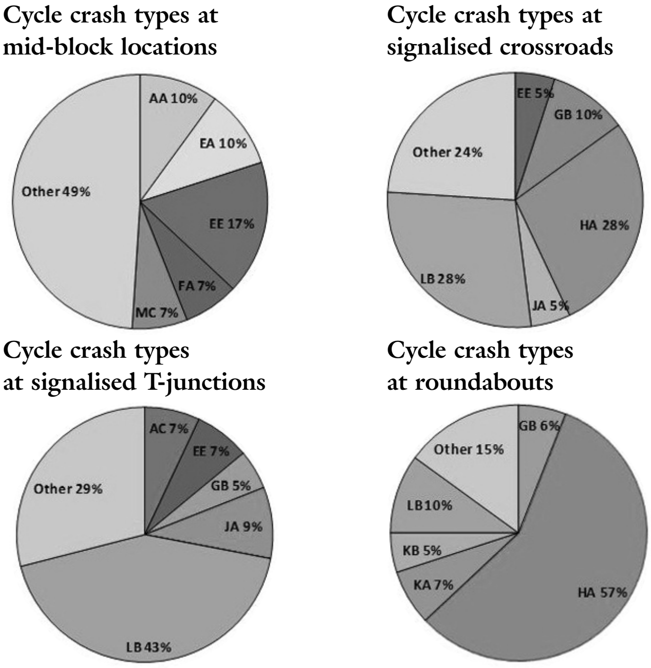

Figure 3. Cycle crashes by crash coding for each site type (refer to coding in Appendix A)

Table 3 shows the number of reported crashes involving a cyclist at traffic signals, roundabouts, mid-block and other locations during the period 1993 to 2002 for the cities used in Study 1.

Traffic and cycle volume analysis

The raw volume data was adjusted for hourly, daily and seasonal variations using adjustment factors. Separate factors were used for both motor vehicles and cyclists, as described below, to convert the raw traffic volume data to typical daily flows.

Weekly, daily and hourly correction factors from the *Guide to Estimation and Monitoring of Traffic Counting and Traffic Growth* [12] were applied to the raw traffic count data to determine the Annual Average Daily Traffic (AADT) volume for each turning movement, that is,

$$AADT = \frac{V}{HF} \times DF \times WF$$

where V=Hourly vehicle counts, HF=Hourly Factor, DF=Daily Factor and WF=Weekly Factor. The flow profile for the study sites for each New Zealand city was assumed to be Urban Arterial Strategic.

The AADT that was used for each movement at each site was the average value of AADT calculated from each set of hourly counts on the survey day. The AADTs were also factored using an annual traffic growth factor to the mid-point of the five-year crash analysis period used to build the crash prediction models.

Correction factors for cycle volumes were calculated using a similar methodology to that adopted for motor vehicles. A term factor representing cycle volume adjustments during each

Table 3. Cyclist versus motor vehicle accidents, 1993-2002 (row percentages included)

City	Traffic signals	Roundabouts	Mid-block	Other	Total
Christchurch	259 (15%)	157 (9%)	360 (22%)	898 (54%)	1674
Hamilton	42 (11%)	48 (12%)	75 (19%)	222 (57%)	387
Palmerston North	30 (9%)	38 (11%)	74 (21%)	207 (59%)	349
Totals	331 (14%)	243 (10%)	509 (21%)	1327 (55%)	2410

school term in a year was used in place of the weekly factor. The flow profiles for the study sites in each of the New Zealand cities were assumed to be the combined profiles of commuter and school cyclists.

Model development

The crash prediction models were developed using generalised linear modelling methods. Minitab macros were used to produce the models from the data collected for each sample set in each of the studies. By way of example, Equation 1 shows an equation from Study 2 for mid-block cycle crashes (crashes between motor vehicles and cyclists).

$$A = 8.60\text{x}10^{-3}\text{x } Q^{0.25}\text{x } C^{0.17}\text{x } L^{0.37} \qquad \text{Equation 1}$$

where Q is 2-way daily traffic volume, C is the daily cycling volume and L is the segment length.

Further details on the modelling methods, including the various 'motor vehicle versus cyclists' models developed and the goodness-of-fit test results, can be found in Turner et al. [11] Also refer to Turner et al. [13] for a more complete summary of the models that have been developed at urban intersections in New Zealand, including traffic signals, roundabouts and mid-block locations.

Modelling results

An examination of the crash prediction models from Studies 1 and 2 can provide insights into how cycle crashes are influenced, both positively and negatively, by various operational and physical variables. The crash relationships are presented here in the form of graphs, figures and reduction rates, rather than mathematical models, so that the results are immediately apparent. While general trends are evident in terms of a positive or negative impact on safety and whether the individual crash risk goes up or down across the range of variables (shown by the shape of the curve), care must be taken when making predictions for actual intersections or links, given the limited number of crashes observed at some sites and the stochastic nature of crashes. Readers should also be aware that the parameter values in cross-sectional models are influenced by the variables that are included in each model (and those that are not) and the correlation between variables.

Traffic and cycle volumes – the 'safety in numbers' effect (from all three studies)

There have now been a number of crash prediction models developed by the research team relating 'motor vehicle versus cyclist' crashes to traffic and cycle volumes (flow-only models). The models show a non-linear relationship between crashes and volumes for cycles and traffic. The traffic volume variables tend to have an exponent of around 0.5, indicating a square-root relationship. For cycle flows, the exponent is well below 0.5 and often closer to 0.2 or even 0.1. This low exponent indicates a strong 'safety in numbers' effect – i.e., the crash risk per cyclist drops dramatically as cycle volumes increase. This relationship is illustrated in Figure 4 where the modelled crash risk per 10,000 cyclists was found to drop quickly, until starting to level off around 100 cyclists per day for signalised crossroads and closer to 150 cyclists per day on mid-block sections.

This relationship does indicate that cyclists are safer on routes which are well used by other cyclists. It also indicates that cyclists are likely to be safer in cities, towns and parts of urban areas that have a higher proportion of trips by cyclists. This is likely to be due to drivers observing cyclists more regularly and therefore being less surprised when a cyclists crosses their path or is travelling alongside their vehicle. It is also likely that in such towns and cities more car drivers also cycle, and are therefore more aware of cyclists.

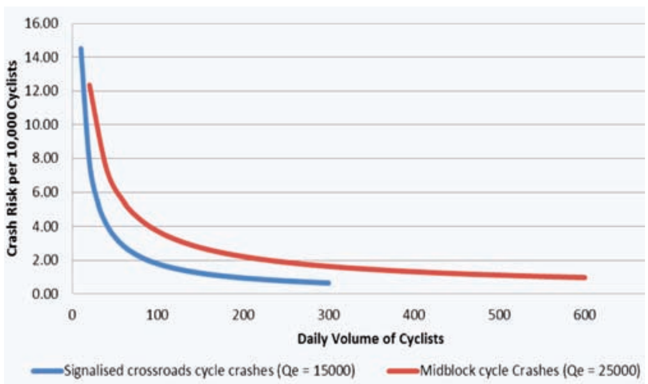

Figure 4. Crash risk per 10,000 cyclists as a function of volume (Qe is entry traffic volume)

Link length (for mid-blocks – Study 2)

The relationship between cycle crashes and mid-block section length is also non-linear. A mid-block section (normally an arterial or collector) usually runs from one major intersection to the next, excluding around 50m on each intersection approach (crashes in this section are attributed to the intersection). Alternatively the mid-block section extends to the end of a road. Figure 5 shows the reduction in risk as the mid-block length increases. The reduction is most dramatic from around 100m to 400m where the cycle crash risk drops from 1.5 to around 0.6 crashes (in five years) per 100m. Given that the most common section length is between 200 and 400m (see Figure 1), this is an important crash predictor variable.

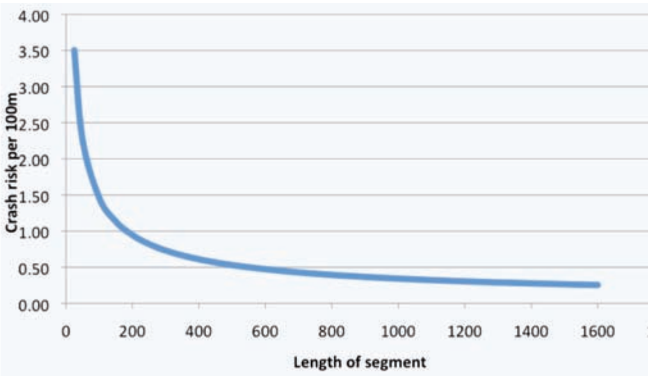

Figure 5. Crash risk per 100m of cycle lane as cycle lane length increases

The shorter mid-block sections often occur in central city shopping areas and other commercial areas around cities and towns, where there are frequent sets of traffic signals. In such environments there is often congestion (at least during morning and evening peak periods), parking turnover is high and it is difficult to provide space for cyclists, either in terms of wider lanes or cycle lanes. It is a complex environment for cyclists. The longer sections tend to occur in suburban areas, where there are fewer intersections and there are fewer impediments to providing wider kerbside lanes or cycle lanes. So it is possible that length does account for a number of variables that do not appear in the models developed so far. Further research is warranted to look at these other variables.

Vehicle speed (from Study 2)

Vehicle speed was also found to be an important predictor variable. Figure 6 shows that the effect of speed reductions on crashes is greater at lower speeds. A reduction from 40km/h to 30km/h will reduce crashes by around 11%, while a reduction from 50km/h to 40km/h, while still effective, only reduces crashes by around 8.5%. Research on roundabouts by Turner et al. [14] shows a similar relationship for both entry and circulating speeds at roundabouts on entering versus circulating crashes, both for 'motor vehicle only' crashes and 'cycle versus motor vehicle' crashes.

While this result may seem surprising, with a much higher proportion of severe and fatal crashes at higher speed, it shows that the biggest gains are achieved at lower speeds. While some reduction in cycle (and pedestrian) crashes may be possible in dropping speed limits from say 60 to 50km/h, much large gains can be made if we drop speeds to around 30km/h. Even at 50km/h there is still a high risk of a fatal crash, but this drops significantly at speeds of 30km/h. This is a reason why there is a lot of support to reduce speed limits to ideally 30km/h in high pedestrian and cycle areas.

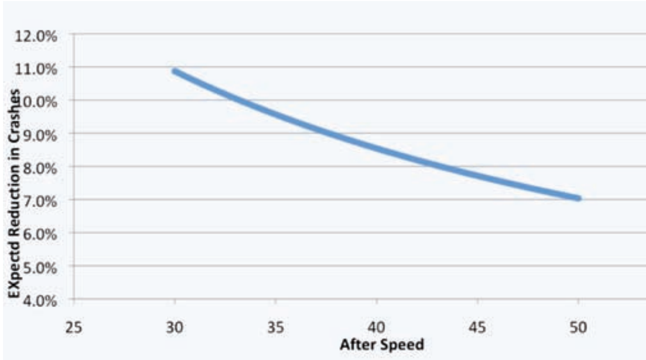

Figure 6. Expected reduction in crashes from 10km/h drop in speed

Road width treatments (from Study 2)

The crash modelling results for the cross-section variables generated some interesting findings that are difficult in some cases to interpret. The key finding that wider kerbside lane widths tended to increase crash rates was not expected. Figure 7 shows the relationship between kerbside lane width and crash rates.

In interpreting this result, the context of these kerbside lanes needs to be considered. Some of the road sections have cycle lanes and other have flush (painted) medians, which effectively reduce the kerbside lane width. While the effect of these variables on crash rates has been assessed in some of the models, a combined model with all the factors has not been developed. So where the kerbside width appears alone with cycle and traffic volume, it is in effect acting as a surrogate for the presence of cycle lanes and flush medians on most of the relatively wide Christchurch roads. Another effect is that roads with wider traffic lanes are more likely to have higher speeds, which may also explain higher crash rates for wider kerbside lanes.

The crash modelling showed that flush (or painted) medians, which are normally installed to reduce 'motor vehicle and pedestrian' crashes (by creating a median for right-turning vehicles and crossing pedestrians), also produce safety benefits for cyclists. A reduction of 37% in crashes when a flush median was present was predicted by the crash prediction models.

The benefit of cycle lanes was mixed, with the crash prediction models showing an increase in cycle crashes. When a before-and-after analysis was undertaken of sites where cycle lanes had

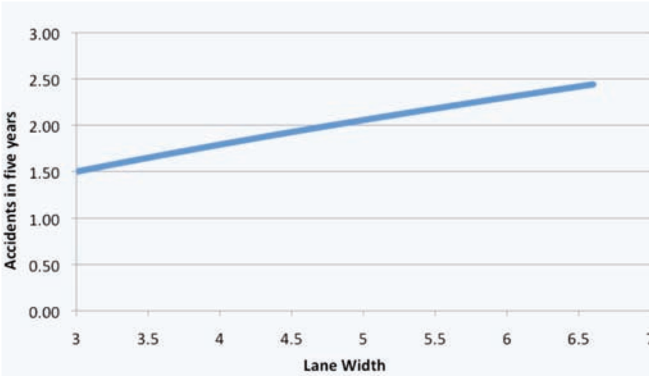

Figure 7. Relationship between kerbside lane width and crashes

been installed, however, it was found that there was a 10% reduction in crashes. This seems a little low compared to overseas studies (where reductions of around 20% have been observed) and may be due to some narrower and below-standard cycle lanes being in the sample set. The increase in crashes observed in the crash prediction models was thought to be due to bias in the sites that are selected to have cycle lanes, with cycle lanes more likely to be installed on roads with higher cycle crash rates.

Parking provision (from Study 2)

The presence and utilisation of parking was found to be an important variable in the models. The absence of parking showed a reduction in cycle crashes of approximately 50% (see Figure 8). In terms of parking utilisation, those sites with relatively high levels of parking tended to have a neutral effect on crash rates. Those sites with low parking utilisation had almost twice as many crashes (85% more) as sites that had higher utilisation of parking.

The most likely explanation for this is that cyclists tend to use the parking shoulder when the parking utilisation is low, but at times have to pass parked vehicles, which creates a potential conflict point with car drivers, who may be taken by surprise. This matter does deserve further research, as does the benefit of painted medians, which may give drivers more space when they encounter cyclists.

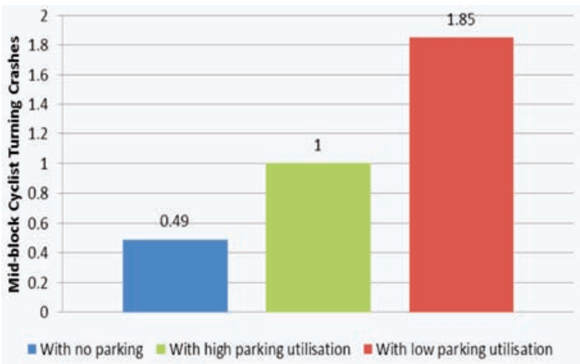

Figure 8. Impact of parking on cycle crash rates

Cycle treatments at traffic signals (from Study 3)

An initial analysis of the latest study, using the signalised intersections in Christchurch, produced results which consolidate those found in earlier studies. A crash model with vehicle and cycle flows produced exponents (coefficients 'b' in the earlier specification) for vehicles of 0.5 and for cycles of 0.3, confirming the 'safety in numbers' effect of earlier studies. These changed to 0.65 and 0.2, respectively, when 'right turn against' only crashes are used. This indicates that' right turn against' crashes decrease more with increased cycle flow for a given vehicle flow than all crashes combined.

A before/after control/impact analysis of the effectiveness of cycle installations, using the empirical Bayes method of Hauer [15] revealed that cycle installations have little effect on the crash rate (for the study period 2001-2005, the expected crash rate without installation was 0.36, while the observed crash rate with installation was 0.34). Painting of cycle lanes, however, was found to be effective. There are a number of other variables that are likely to impact on cycle crash occurrence, including intersection depth (at traffic signals cyclists may get caught in wider intersections when traffic signals change), traffic signal phasing and number of traffic lanes (which means right-turning vehicles have to cross through more traffic to turn right). Each of these variables will be examined in future crash prediction modelling studies.

Conclusions

There are few studies internationally that have developed prediction (regression) models for crashes involving cyclists. This is despite the potential for such models to improve our understanding of the relationship between cycle crashes and a number of physical and operational variables. Three studies have been undertaken in Australasia, one of which is still in progress. In these studies, data has been collected on crashes, traffic volume, cycle volume and a number of other crash predictor variables (road cross-section, intersection layout, cycle facilities and motor vehicle speed). The studies have examined cycle crashes at traffic signals (around 7% of cycle crashes), roundabouts (9%) and mid-blocks (42%), with more detailed evaluation of traffic signals and mid-blocks.

The crash models produced in these studies have provided an insight into the relationship between cycle crashes and a number of road factors. The strongest relationship is between crashes and cycle and traffic volumes. The crash models show a 'safety in numbers' effect, with the potential for large reductions in crash risk per cyclist as cycle volumes increase. The modelling to date indicates that there are big reductions in risk when flows reach 100 cyclists per day per approach at traffic signals and 150 cyclists per day on mid-block sections. As traffic volumes increase the number of cycle crashes increase, although at a reduced rate.

The crash models also indicate a significant reduction in crash risk as speeds reduce. The reduction in crashes increases as speed lowers. For a 10km/h drop from 50km/h to 40km/h there is around an 8.5% reduction in crashes, while this increases to an 11% reduction when the speed drops from 40km/h to 30km/h. The findings for speed and traffic volumes are consistent with the UK five-step hierarchy of cycle improvements, which favours reduction in traffic volumes and speed before other interventions. The benefit is greater at lower speeds, as it is much safer to reduce speeds down from say 60km/h to 30km/h, than only 50kph, where the risk of a fatal crash is still relatively high.

The findings that crash risk reduces as cycle volume increases should be acknowledged at this stage as simply an association between the two measures. It may be a causal relationship, in that, for example, the increased visibility of a higher cyclists flow prevents accidents that would occur at lower flows. Alternatively, it may be only an association, in that, for example, higher cyclist flows only occur on inherently safer routes. Further research is required to settle this current uncertainty.

Crash rates appear to increase as link lengths reduce. Link lengths tend to be shorter in commercial areas, particularly in the middle of cities, where large intersections are more closely spaced. Hence this variable may be a surrogate for high parking turnover, high traffic volumes and higher densities of access-ways. The research shows that the crash rate for a 400m road link is almost a 1/3 of that for a 100m road link. With a number of road links (in the sample set at least) between 200m and 400m in length, it is important that cycle safety is given significant attention for shorter road links.

The research on road cross-sections so far only provides part of the picture in terms of the best combination of cycle lane, kerbside lane width and provision of a flush median. The findings do indicate around a 10% reduction in cycle crashes when cycle lanes are provided. This is perhaps on the low side, given that the sample set contained some of the older cycle lanes in Christchurch, some of which were of lower standard (e.g., narrower width) than more recent cycle lanes. The study also showed that flushed (painted) islands lead to a 37% reduction in crashes.

The results on lane width actually showed that narrower lane widths were safer. This result was unexpected. Given the form of the model, however, it is likely that the narrower lanes were associated with roads that had cycle lanes or flush medians or both. Hence it indicates that it is better to provide these extra facilities and narrow the traffic lanes, than to leave wide traffic lanes, where speed management is difficult. Further analysis of the data collected should provide more insights.

As shown elsewhere, the removal of parking results in a large reduction in crash occurrence, at around a 50% reduction. When parking is provided, it is better that it be fully utilised. Roads with low utilisation of parking have almost twice the crash rate (an 85% increase) than roads with high utilisation. The most likely reason for this increase is that cyclists utilise the parking shoulder for most of their journey, but at intervals have to pass parked cars. This may in turn create a potential conflict with passing motor vehicles, as the cyclists move out into the traffic lane. An area of future research is to examine how flush medians may provide the extra room that is required for motorists to take evasive action during such events.

A study is currently underway, using a before/after control/impact design with data from signalised intersections in Christchurch and Adelaide, examining the impact of cycle installations on safety. Variables being considered are vehicle flow, cycle flow and design aspects of the cycle installation, as well as the geometry of the intersection. Results will be fully reported in the literature when the study is complete. Current research studies will look at a number of new variables at intersections, including how intersection depth may impact on right angle (or red-light running) cycle crashes; how signal phasing, particularly right turning phasing, may impact on 'right turn against' crashes; and how the number of lanes impacts on crashes involving right-turning cyclists.

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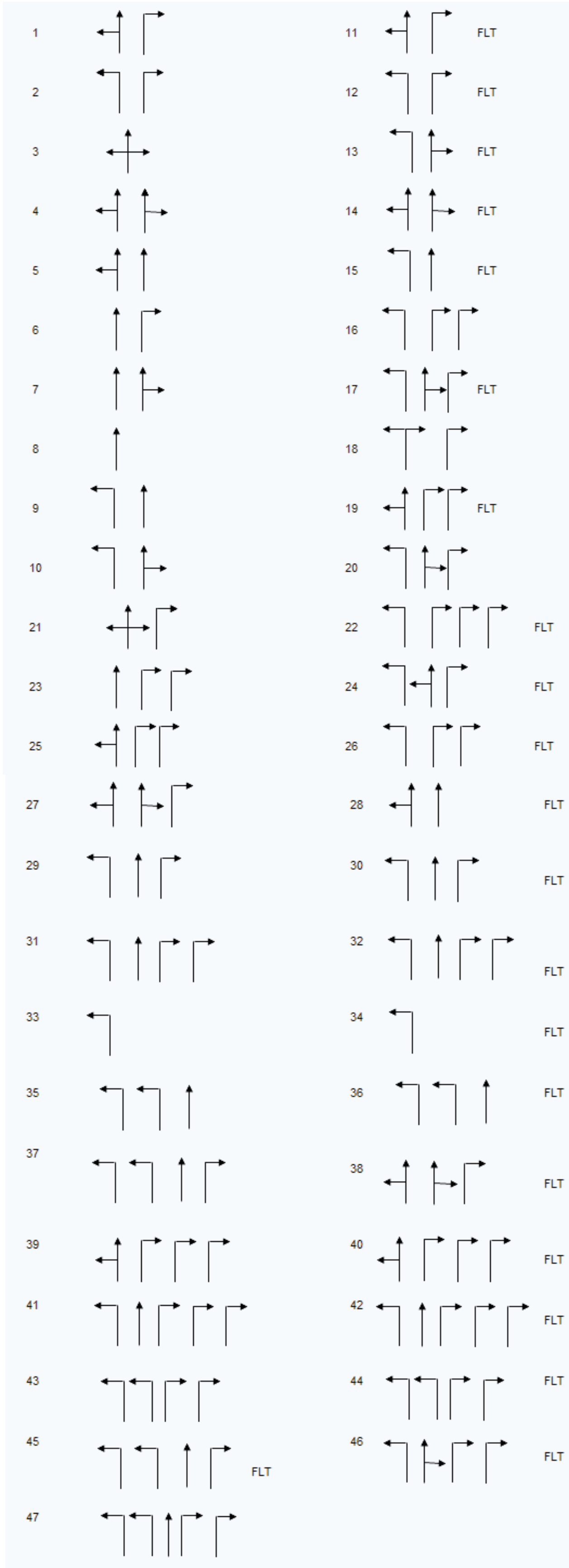
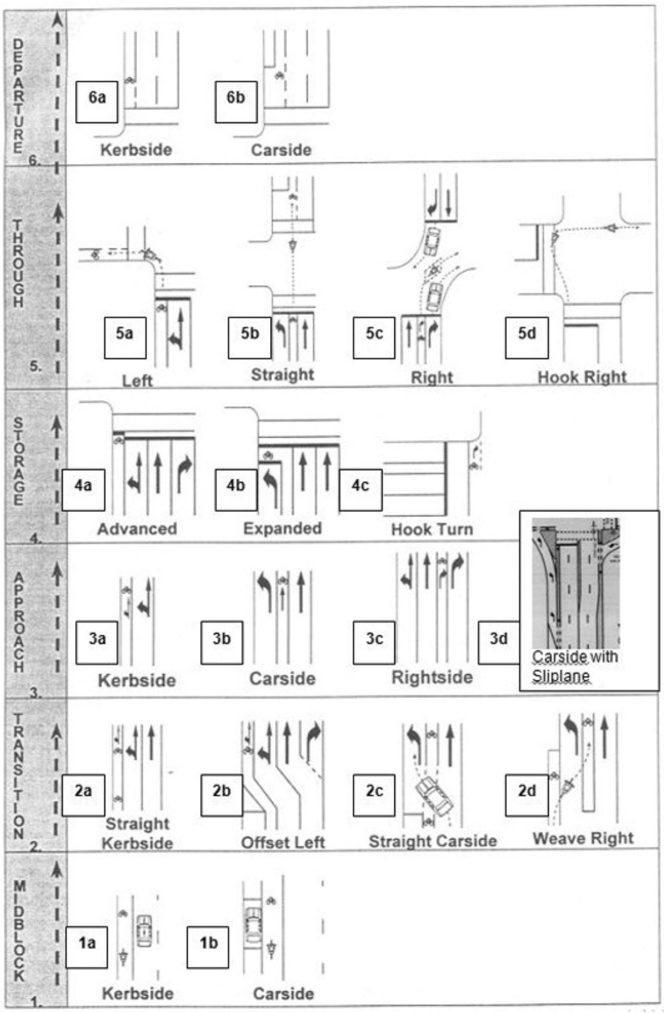
Appendix A – Lane layout coding chart



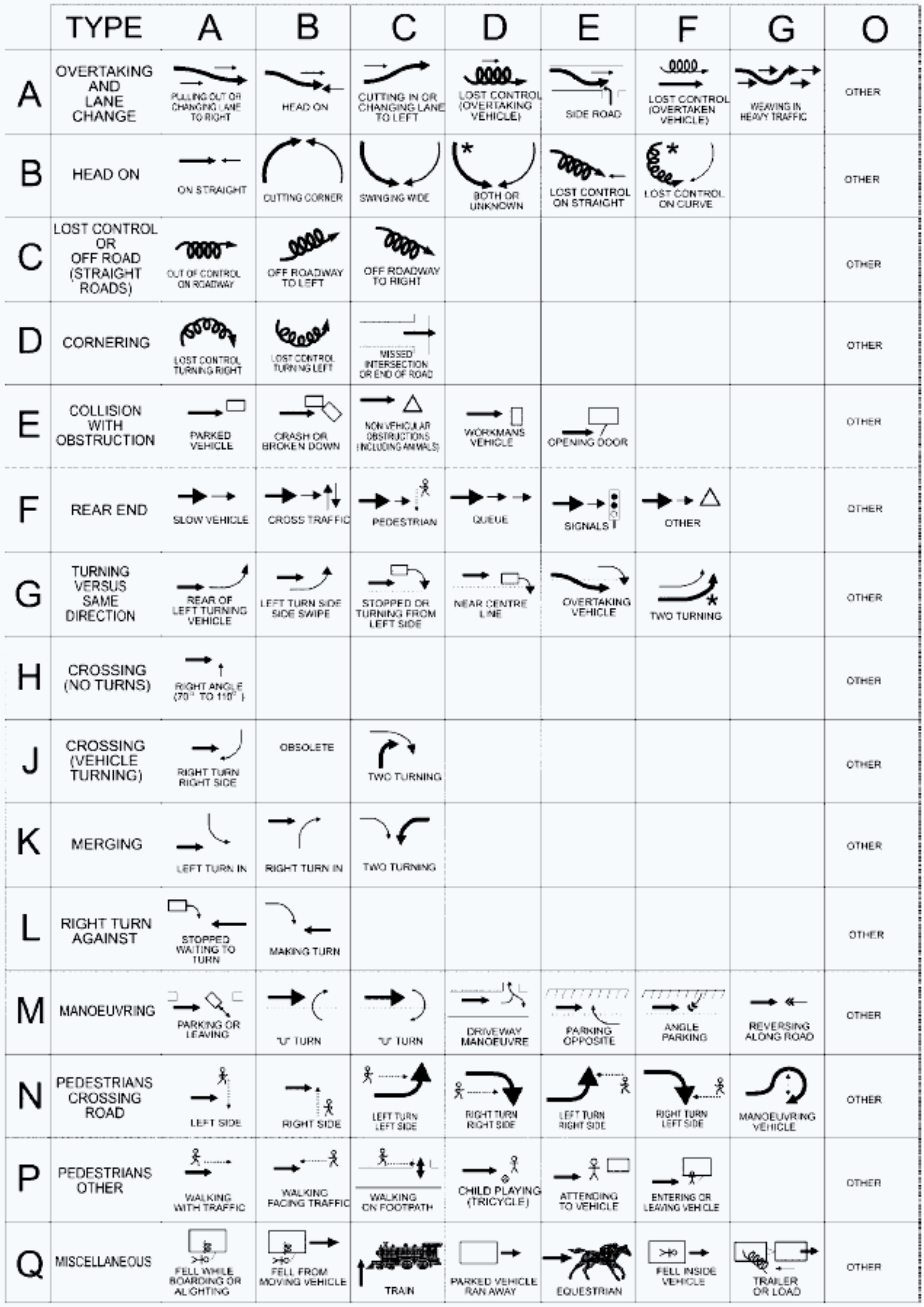
Appendix B – Cycle treatment chart



xxp: painted
For example
3ap: painted kerbside approach

xn: no treatment
For example
2n: no transition treatment

Appendix C – NZ crash collision diagram



* = Movement applies for left and right hand bends, curves or turns