CRASH ESTIMATION COMPENDIUM

New Zealand crash risk factors guideline

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Glossary

A_S	Site-specific crash rate (reported injuries)
A_T	Typical crash rate (predicted injuries)
AADT	Annual average daily traffic
Austroads	National Association of Australian Road Authorities
C	Daily cycle volume
CAS	Ministry of Transport's Crash Analysis System
CMF	Crash modifying factor
CRF	Crash reduction factor
DSi	Number of deaths and serious injury casualties. May be reported, estimated or predicted. The term FSi is used in this manual instead of DSi as crash numbers are used in the NZ Economic Evaluation Manual.
EEM	Economic Evaluation Manual
FSi	Number of fatal and serious injury crashes that involve at least one death or serious injury. May be reported, estimated or predicted. A crash may involve several deaths and serious injuries. Crash numbers are used in economic evaluation.
HRIG	High-risk intersection guide
HRRRG	High-risk rural roads guide
Intersection	For the purposes and clarity for using the guide an intersection is: • Where two or more streets or roads join or cross, or • Where a major public driveway joins a street or road and is constructed as an intersection. (Note: it is easy to overlook these when searching in CAS.)
Mid-block	Road sections ≥ 50m from an intersection.
NZTA	New Zealand Transport Agency
ONRC	One Network Road Classification
P	Daily pedestrian crossing volume
Q	Daily traffic volume
Severity Factors	The expected ratio of FSi crashes to all injury crashes.

Contents

1.0 Introduction

This manual presents methods for estimating (police) reported injury crash predictions for various road and site elements in New Zealand. A full list of road and site types currently covered by this manual are outlined, including the transport modes covered by these models and factors. This is the first amendment of the Compendium. There are known gaps in the crash models, rates and crash reduction factors that are currently available for use in New Zealand. The intention is to address these gaps in future versions of the manual.

While this manual has been prepared as a compendium to the NZ Economic Evaluation Manual (EEM) the models, rates and reduction rates, along with severity factors have a wider range of use under a safe system approach, than just economic evaluation. For example the underlying crash rate at a site or along a route, and especially the risk of fatal and serious crashes, can be estimated with more reliability using the models and severity ratios. Historical crash data, especially for more severe crashes and fatalities can be very variable, and the crash predictions allow an analyst to assess whether the history reflects an underlying crash risk or are just showing a spike in crash risk that is unlikely to be repeated. A safe system approach needs to focus on the areas of high underlying risk of such crashes, rather than respond to a one off crash occurrence.

A key role of the manual is to allow an assessment of the effectiveness of safety improvement works. Crash reduction factors (CRF) and crash modification factors (CMF) have been provided for a variety of different road features and safety improvement countermeasures. The factors have been developed in evaluation studies using police reported injury crashes. The crash reduction factors have been developed for different crash types, level of severity and different transport modes (e.g. crashes involving pedestrians only). CMFs have been derived for all injury crashes or for all injury crashes involving a transport mode. Many of the CMFs and CRFs have been developed or collated as part of Austroads research.

Under-reporting of police reported crashes is not considered in this manual. While fatal crashes are often assumed to be 100% reported, for minor and serious crashes reporting rates are at best 50% and often lower. Reporting rate factors are found in Appendix A6 of the NZ EEM. The crash rates and models also do not consider non-injury crashes. Further advice on non-injury crashes can be found in Appendix A6.

The manual also includes severity factors for different routes and site types. These factors allow the risk of fatal and serious injury crashes to be estimated from predictions of total injury crashes (fatal, serious injury and minor injury). These factors are new and limited due to sample size restrictions for some sites and crash types. Care should be taken in their use.

The crash rates, crash prediction models, CRFs, CMFs and severity factors presented here are not exhaustive and analysts are permitted to use other research that is available, as long as the robustness of this research can be demonstrated in the New Zealand (and Australian) context. Crash reduction and crash modifying factors used from outside of the compendium need to be fully referenced (for example papers, research reports or unpublished material), along with information on sample size, modelling technique, goodness-of-fit statistics, and confidence levels stated. Alternative crash rates and crash prediction software may also be used provided they are calibrated to New Zealand conditions.

For intersection and mid-block crash prediction models, analysts are referred to the appropriate research report on crash prediction models in the reference section. The crash prediction models in these reports are more extensive than provided in the manual and may be useful when looking at some crash counter-measures.

However the model parameters may need to be adjusted given the downwards trends in crashes and because many of the models predict crashes over five years rather than one year.

This document has been formed as a compendium to the EEM, and is to be used in conjunction with the EEM when applying EEM appraisal method B (crash analysis) and method C (weighted crash analysis).
Section 2 of the manual provides an outline of the methodology that is used to calculate crash predictions using the various analysis tools. Sections 3 to 7 provide the crash rates and crash prediction models that can be used for rural links, urban links, intersections, railways crossings, curves and narrow bridges. Section 8 includes common CRFs and CMFs for different link and site types that can be used to assess the effectiveness of various safety countermeasures. Section 9 includes the severity factors that are used to estimate the risk of serious injury and fatal crashes at a site.

2.0 Methodology

2.1 Model predictions

The crash rate and crash prediction models in this manual, unless otherwise stated, have been developed for the most common types of site in each category. For example, traffic signal models were generally developed for two and three phase signals, and are therefore are not as accurate for signals with four or more phases, or where there are a lot of phase changes during set periods of the day. The models and rates are most valid within the flow ranges provided. Analysts should exercise caution when using the models and rates outside these ranges.

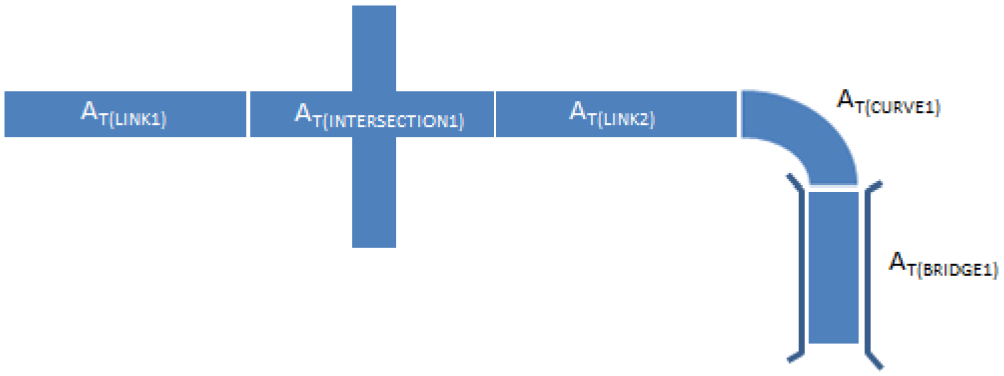
The more unusual a site is from the typical site type, the less appropriate the general models and equations will be for predicting the typical crash rate. In most cases where there is a feature of a site, such as the site's layout, that has a significant effect on the crash rate, the rates and models in this manual are not likely to be appropriate.

The models presented here deal with (reported) injury crashes only. Crashes and casualties have a close statistical relationship. There are a number of factors; such as the number of vehicle occupants; that can be used to determine casualty numbers using the established crash numbers. Refer to the HRIG (NZ Transport Agency 2013) and HRRRG (NZ Transport Agency 2011) for more information on this relationship.

Generally all flow models are suitable for most mid-block or intersection types indicated. Where a breakdown of crashes by crash type or road user type is required; or, in the case of intersections, where the proportion of turning vehicles is high compared to through vehicles, then more detailed conflicting flow models by crash type and movement should be used.

2.1.1 Methodology by site and crash type

Many projects are made up of multiple site types, including links (of different traffic volume and speed), intersections, bridges, curves and railway crossings (see figure example below). To estimate the total number of crashes at a site the predictions for each site type must be calculated and added together ($A_{TOTAL} = A_{T(LINK1)} + A_{T(CURVE1)} + A_{T(INT1)}$ …).



For intersections, crashes that are 50 metres up each leg are attributed to the intersection. In a similar way, crashes around bridges and railways crossing extend up to approximately 50 metres from the site. Mid-block crash rates generally exclude 'major' intersection crashes. Midblock crash rates and crash prediction models do include crashes at accesses and lower volume intersections. It is acknowledged that the cause of a crash may not always be contained within the 50 metre buffer. At major intersections traffic queuing may at times extend beyond 50 metres from the limit lines and cause crashes. Likewise there may be mid-block type crashes that do occur within the intersection buffer area that are not attributed to the intersection. These limitations of the crash rates and crash prediction models need to be considered in analysis.

For some improvement projects it is necessary to predict crashes at a site by type and/or mode (for example intersections ($A_{T(INT)}$)). At a high level this may be separating out crashes involving pedestrian and cyclists from motor-vehicle only crashes (e.g. $A_{T(INT)} = A_{T(PED)} + A_{T(CYCLE)} + A_{T(MOTOR\ VEH)}$). This is required when different improvements are focused on different transport modes (e.g. the installation of a new pedestrian crossing facility or a new cycle lane).

It may also be necessary to look at specific crash types (see Appendix A for NZ crash codes) for a particular mode. Some improvements, such as the installation of a right turn bay at a rural intersection or installation of right turn signal phase at an urban signalised intersection only impact on some crash types. Models by crash type are called conflicting-flow crash prediction models (for example motor vehicles ($A_{T(MOTOR\ VEH)}$)). Several conflicting flow models are available by site type for different transport modes. The crash predictions by crash type and approach need to be added together to produce total crashes for each mode (e.g. $A_{T(MOTOR\ VEH)} = A_{T(HA\ App\ 1)} + A_{T(HA\ App\ 2)} + A_{T(HA\ App\ 3)} + A_{T(HA\ App\ 4)} + A_{T(LB\ App\ 1)} + A_{T(LB\ App\ 2)} + A_{T(LB\ App\ 3)} + A_{T(LB\ App\ 4)} + A_{T(F\ App\ 1)} + A_{T(F\ App\ 2)} + A_{T(F\ App\ 3)} + A_{T(F\ App\ 4)}$ ....)

2.1.2 Crash model types

The five models groups that presented in the compendium are shown in Table 1.

Table 1: Crash rates and crash prediction model types

Rural Roads (2 and 3 lane mid-blocks sections) ≥ 80km/h	Rural two-lane roads (by ONRC and terrain type) Two-lane roads with passing lanes Rural isolated curves Single lane rural bridges Two-lane rural bridges
Multi-lane High Speed Roads	Motorways Four lane divided rural roads (expressways – with either wide grass medians or physical median barriers)
Urban Roads (Mid-blocks) 50-70km/h	Urban mid-blocks (by road hierarchy) Urban Arterials with ≥ 6 lanes
Product of Flow Models - Intersections	General urban cross and T-junction intersection 50-70km/h General urban roundabouts 50-70km/h General high speed roundabout ≥ 80km/h on one approach Urban and Rural railway crossings
Conflicting Flow Models - Intersections	Urban signalised cross roads <80km/h Urban roundabouts <80km/h High speed priority crossroads >70km/h High-speed priority T-junctions >70km/h

The rates and models present in this compendium have either been developed exclusively for the NZ Transport Agency EEM (1) or as part of a research project. In the latter case reference of the relevant research report has been provided. In many cases the original models have been modified for this compendium to include the downward trend in crashes since the models were developed.

2.1.2.1 Rural Road Mid-block Crash Rates

General rural road crash rates are suitable for most rural mid-block analysis, except those with continuous four or more lanes. For multiple-lane roads use the crash prediction models provided for motorways and 4-lane divided roads. Passing lane and short 4-laned sections (double passing lanes), can be assessed using a crash modifying factor (CMF). For bridges, isolated out-of-context curves, railway crossings and major intersections use the other crash models provided.

The rural 2-lane mid-block crash rate has the following form:

Injury crashes per year (A_T) = crash rate (b_0) x Exposure (volume) x ∑CMFs

∑Crash Modifying Factor (CMF) = $CMF_1 * CMF_2 *$ ... (e.g. lane and shoulder width)

Exposure (mid-blocks) = L x AADT x 365 / 10^8

Where:
AADT = annual average daily traffic
L = length (km)

Crash prediction models are also available for rural roads in New Zealand. Refer to research by Turner et al (19) and Cenek and Davis (14). While these models maybe useful for evaluating rural realignments, they have not as yet been fully assessed for use in economic evaluation. Once this process is completed these models may be added to future versions of this guideline.

2.1.2.2 Urban Road Mid-blocks

Crash prediction models are used to estimate injury crashes at urban mid-block sites. The reported injury crashes per year is dependent on roadside development. Separate pedestrian and cyclist injury crash models are also available.

The urban 2 and 4 lane mid-block crash prediction model has the following form:

Injury crashes per year (A_T) = b_0 x Q^{b1} x L x ∑CMFs

∑Crash Modifying Factor (CMF) = $CMF_1 * CMF_2 *$ ... (e.g. solid and flushed medians)

Where:
b_0 and b_1 = model parameters
Q = annual average daily two-way traffic volume
L = length (km)

Major intersections and railway crossings should be assessed separately using either the product-of-flow or conflicting flow crash prediction models.

2.1.2.3 Product of Flow Models – Intersections

Two types of crash prediction model are available for intersections. High level product-of-flow models predict total injury crashes based on the product of the traffic volumes on the two roads that are intercepting. Separate models are available for different forms of control and for cross roads and T-junctions. These models should only be used when analysing intersection changes that impact on all injury crashes or for project feasibility analysis. Changes that often impact on all injury crashes include changing form-of-control (e.g. priority control to traffic signals) and traffic volume increases (possibly as a result of a new development). These models are also useful for calculating the injury crash rate at new intersections. For more detailed analysis of intersections conflicting flow models should be applied.

The product-of-flow intersection models have the following general form:

Injury crashes (priority and traffic signals) = b_0 x $Qmajor^{b1}$ x $Qminor^{b2}$ x ∑CMFs

Injury crashes (roundabouts) = b_0 x $Qapproach^{b1}$ x ∑CMFs

∑Crash Modifying Factor (CMF) = CMF_1 * CMF_2 * ... (e.g. lighting and splitter island)

Where:

b_0 and b_1	= model parameters
Qmajor	= annual average daily two-way traffic volume on highest volume road (signals) or priority road
Qminor	= annual average daily two-way traffic volume on lowest volume road (signal) or side-road
Qapproach	= annual average daily two-way traffic volume on each roundabout approach
L	= length (km)

Product-of-flow crash prediction models are also available for different railway crossing control types. These models include both traffic volume and the typical number of train services per day.

2.1.2.4 Conflicting Flow Models - Intersections

Conflicting flow models provide a breakdown of the predicted crashes by road user type (e.g. pedestrian and cyclists) and crash type (refer to Appendix A). Crash type models are usually only available for the major crash types at each intersection. The total number of injury crashes at an intersection is calculated by adding up the crashes by each type and approach and then using either a general/other crash prediction model or a factor to take into account the crashes not modelled.

Conflicting flow models are typically used in analysis when there are a high proportion of vehicles making turning movements, especially right turns and when treatment impacts on particular crash types or crash modes. Examples of the latter include installing a right turn bay at a rural priority intersection and right turn signal phasing at urban traffic signals.

This manual contains a large number of conflicting flow models. The New Zealand research available also has a large number of other crash prediction models. Many of the models include non-flow variables, like speed and road layout factors. Even with the large number of models available there are some major gaps in the range of models provided. In the case that detailed models are not available then analysts may have to use the product of flow models.

Generally CMFs should not be applied to these model predictions, as the CMFs normally apply only to all injury crashes. It is not possible to present a general model form, but two examples are given:

Right turn against crashes (rural priority) = b_0 x q_x^{b1} x q_y^{b2} x RTB factor

Where:

b_0, $b_1$and b_2	= model parameters
q_x and q_y	= various daily turning movement volumes (of which there are twelve at a X-roads and six at a T-junction)
RTB factor	= adjustment to crash prediction (CMF) if right turn bay provided

Entering versus circulating cycle crashes (roundabouts) = b_0 x Qe^{b1} x Cc^{b2} x Speed ^{b3}

Where:

b_0, b_1, b_2 and b_3	= model parameters
Qe and Cc	= daily entering volume for motor-vehicle and circulating volume for cyclists (Cc)
Speed	= Mean speed of traffic entering from each approach

2.2 Crash reduction factors and crash modifying factors

A Crash Reduction Factor (CRF) indicates the expected percentage reduction in crashes following the introduction of a treatment. Crash reduction factors can apply to all injury crashes, crash of a particular severity (e.g. fatal and serious injury), specific crash types (e.g. loss-of-control crashes), by a particular mode (e.g. pedestrian crashes) or by environmental conditions (e.g. night-time and wet-weather crashes). These factors are typically applied to historical crashes to estimate future crash numbers after an intervention. In economic evaluation they are used for Method A – Crash-by- Crash analysis.

The effectiveness of traffic engineering countermeasures in Australia and New Zealand has traditionally been presented using Crash Reduction Factors (CRFs), which presents the expected percentage reduction in crashes. The term Crash Modifying Factor (CMF) is now used more widely overseas, although both terms are used in this manual (Austroads, 2012).

A Crash Modification Factor (CMF) is used to adjust a crash prediction from a crash rate or crash prediction model to reflect a road feature or safety improvement measure that is not reflected in the rate or model. In this manual CMFs are provided for all injury crashes or all injury crash involving a specific mode. Hence they are only applied to models that predict all injury crashes, not to conflicting flow models. Refer to general model forms provided above for how CMFs can be applied in crash prediction.

CMFs have been included in the manual for use in economic evaluation. CMFs should be used for Method B (Crash Rate Analysis) and Method C (Weighted Crash Procedure).

2.3 Severity factors

Severity factors are used to estimating the expected number of deaths and serious injury crash equivalents (A_{FSi}) based on reported injury crashes at a site. To predict the equivalent FSi multiply the all injury predictions calculated by the various crash rates and crash prediction models in this guide by the severity factors

$$A_{DSi} = SF \times A_{TOTAL}$$

Where, SF is the Severity Factor (from tables provided)

A_{TOTAL} is a site's predicted injury crash rate

The expected number of FSi by mode type for a site can also be estimated (for example FSi (pedestrian crashes) = SF (ped) x A_{PED}).

The severity outcome of crashes is influenced by vehicle speeds, intersection and link types, transport mode involved and the crash movement types. The New Zealand Crash Analysis System (CAS) has been used to determine the severity factors of all movement types by vehicle speed, mode and site type. Severity factors by crash type have not been provided in this guide due to accuracy issues associated with sample size.

3.0 Rural Roads (≥ 80 km/h)

This section includes crash rates for rural 2-lane mid-blocks, isolated out-of-context curves and narrow two lane and single lane bridges. Crash prediction models for rural intersections and railway crossings are found in Sections 6 and 7.

3.1 Rural two-lane roads ≥ 80/km

For two-lane rural roads in 80 and 100km/h speed limit areas, the typical crash rate (reported injury crashes per year) is calculated using the exposure-based equation:

Injury crashes per year		= crash rate (b_0) x Exposure(X) x ∑CMFs
∑Crash Modifying Factor (CMF)		= $CMF_1 * CMF_2 *$ … (e.g. lane and shoulder width)
X, Exposure (mid-blocks)		= L x AADT x 365 / 10^8
Where:	AADT	= annual average daily traffic
	L	= length (km)

Coefficient b_0 is provided in

Table 2 and Table 3 for the various levels of the One Network Road Classification (ONRC). The ONRC is the national categorisation of roads based on their functions; refer to (20) for details on each road category. The horizontal alignment category is based on bendiness and is defined in Table 4. The alignment ranges should generally be maintained throughout the road section. The k-value is used in economic evaluation (Method C). The coefficient b_0 is applicable to a given mean seal width. The CMFs for seal widths are provided in Table 5, and varies according to three road types (grouping of various one network classification types), seal shoulder width and lane width. For road type one, two and three the seal width is assumed to be 9.5 metre, 8.2 metre and 6.7 metre respectively. Other CMFs for rural roads (e.g. for providing shoulder and median barriers) are provided in Section 8.

Operating speed is an important consideration in rural road crashes and the severity of these crashes. The crash rates provided in

Table 2 and Table 3 do include the effects at a high level of operating speed. Operating speeds on a tortuous alignment are generally a lot lower than on a straight alignment, due to the constraints of the curves. What the crash rates don't consider is the consistency of the alignment. A consistent alignment is less likely to catch drivers out, as they can maintain a constant speed. Out-of-context curves occur where there is a large speed change required to negotiate the curve or series of curves. For isolated curves the rates in the next section can be used to predict the impact on crash occurrence. For more complicated alignments including a variety of curves and straights analysts need to use a rural road crash prediction model if a more accurate crash prediction of injury crashes and serious and fatal crashes is required (refer to 14 and 19).

The speed limit on a rural road can impact on operating speed and the associated change in injury crash rates and crash severity (i.e. the proportion that are serious or fatal). Speed limit reductions rarely reduce speeds by the full reduction applied (e.g. a 10 km drop in speed limit may only reduce operating speeds by 3 to 5 km/h). The speed reduction can be particularly low or zero when the speed limit is still above the roads normal operating speed. The power models developed by Elvik et al (11) can be used to assess the crash benefits of reducing operating speeds by speed limit reductions.

Table 2: Rural (State Highways) two-lane roads by horizontal terrain type

One Network Classification	Horizontal Alignment	b_0	K
National Strategic (High Volume)*	Straight	8	0.9
	Curved	16	0.9
	Winding	29	1.2
	Tortuous	35	1.2
National Strategic	Straight	13	0.9
	Curved	19	0.9
	Winding	29	1.2
	Tortuous	35	1.2
Regional Strategic	Straight	13	3.0
	Curved	18	3.0
	Winding	31	1.2
	Tortuous	35	1.2
Arterial	Straight	13	3.0
	Curved	22	3.0
	Winding	31	1.2
	Tortuous	35	1.2
Primary Collector	Straight	18	3.0
	Curved	23	3.0
	Winding	34	4.2
	Tortuous	35	3.0
Secondary Collector	Straight	18	3.0
	Curved	29	3.0
	Winding	34	3.0
	Tortuous	35	3.0

*As outlined in section 5.0 the crash rate for well-designed 4-lane motorways and four lane divided road is in the order of 3 to 8 crashes per 100MVKT. For 6 plus lane motorways refer to the models in Section 5.0.

Table 3: Rural (local) two-lane road coefficients by horizontal terrain type

One Network Classification	Horizontal Alignment	b_0	k
National Strategic (Including High Volume)	Straight	8	0.9
	Curved	16	0.9
	Winding	29	1.2
	Tortuous	35	1.2
National Strategic	Straight	14	0.9
	Curved	19	0.9
	Winding	29	3.0
	Tortuous	35	3.0
Regional Strategic	Straight	18	1.2
	Curved	23	3.0
	Winding	31	1.2
	Tortuous	35	3.0
Arterial	Straight	20	2.3
	Curved	23	3.0
	Winding	31	1.2
	Tortuous	35	1.2
Primary Collector	Straight	25	3.0
	Curved	29	3.0
	Winding	37	4.2
	Tortuous	37	3.0
Secondary Collector	Straight	24	3.0
	Curved	29	3.0
	Winding	34	3.0
	Tortuous	35	3.0
Access	Straight	24	3.0
	Curved	33	3.0
	Winding	33	3.0
	Tortuous	34	3.0
Access (Low volume)	Straight	24	3.0
	Curved	33	3.0
	Winding	33	3.0
	Tortuous	34	3.0

Table 4: Horizontal Alignment Classification

Horizontal alignment type	Degrees/km
Straight	0-50
Curved	50-150
Winding	150-300
Tortuous	>300

Table 5 provides modification factors for two-lane rural crash rates for various combinations of seal widths that differ from the mean seal widths assumed for that road type. First, the overall seal width, shoulder width and lane width are determined. Then, look up CMF that corresponds to the Road Type/One Network Road Classification, shoulder width and lane width in Table 4. Adjust b_0 by multiplying with the modification factor and use this value to calculate the typical crash rate. In the case of shoulder widening, different modification factors would be used for the do-minimum and option.

Table 5: Cross-section crash modifying factors (CMFs)

CMFs for Road Type 3 (Secondary Collector and Access)					
Seal shoulder width	Lane width				
	2.75m	3.00m	3.25m	3.50m	3.60m
0m	1.17	1.10	1.03	0.96	0.93
0.25m	1.10	1.03	0.96	0.89	0.86
0.50m	1.03	0.96	0.89	0.82	0.79
0.75m	0.89	0.82	0.75	0.68	0.66
1.00m	0.75	0.68	0.61	0.55	0.52
1.50m	0.61	0.55	0.48	0.41	0.41
2.00m	0.48	0.41	0.41	0.41	0.41

CMFs for Road Type 2 (Arterial and Primary Collector)					
Seal shoulder width	Lane width				
	2.75m	3.00m	3.25m	3.50m	3.60m
0m	1.47	1.38	1.30	1.21	1.17
0.25m	1.38	1.30	1.21	1.12	1.09
0.50m	1.30	1.21	1.12	1.03	1.00
0.75m	1.20	1.13	1.01	0.87	0.83
1.00m	1.07	1.01	0.85	0.71	0.65
1.50m	0.77	0.69	0.60	0.54	0.51
2.00m	0.60	0.51	0.51	0.51	0.51
CMFs for Road Type 1 (National and Regional Strategic)					
Seal shoulder width	Lane width				
	2.75m	3.00m	3.25m	3.50m	3.60m
0m	2.11	2.01	1.90	1.79	1.74
0.25m	2.01	1.90	1.79	1.67	1.58
0.50m	1.90	1.79	1.67	1.45	1.36
0.75m	1.79	1.67	1.45	1.22	1.18
1.00m	1.67	1.45	1.22	1.11	1.07
1.50m	1.22	1.11	1.00	0.89	0.85
2.00m	1.00	0.89	0.78	0.66	0.66

3.2 Rural isolated curves ≥ 80km/h

Figure 1and the equation below provide typical crash rates for reported injury loss-of-control and head-on crashes on rural curves, adjusted for the general trends in crashes (see Jacket, 13, for original crash rates). They should be used only for an isolated curve that is replaced with a single curve of a higher design speed.

The data for typical injury crash rates has been based on sealed rural state highways. An underlying assumption is that the road section under consideration is not affected by ice or other adverse factors such as poor visual conditions.

The typical crash rate (reported injury crashes per year, by CAS movement categories B, C and D) for an isolated rural curve is calculated using the equation:

$$A_T = b_0 X e^{(b_1 S)}$$

where: $b_0 = 3.55$

$b_1 = 2.0$

X is the exposure in 100 million vehicles (in one direction) passing through the curve

$$S = 1 - \frac{\textit{Design speed of curve}}{\textit{Approach speed to curve}}$$

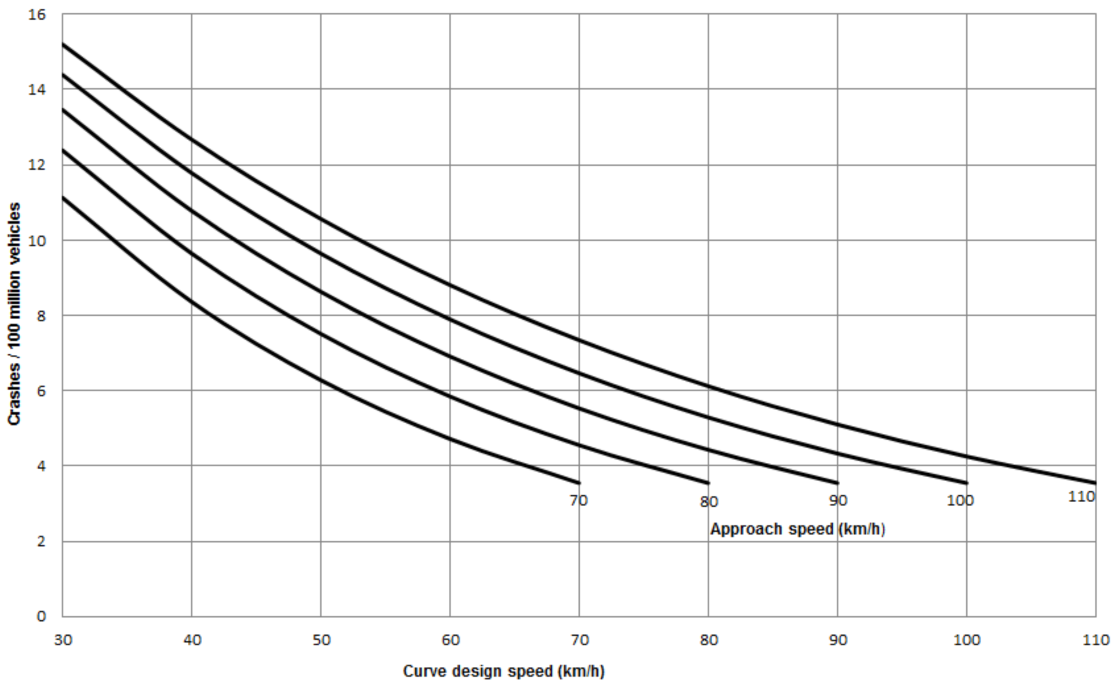
A_T must be calculated for both directions, and S is likely to vary between the two directions (a k value of 1.1 is used in the weighted crash procedure). If the design speed is approximately equal to the approach speed then the equation reduces to:

$$A_T = b_0 X$$

The following assumptions apply when using the equation or Figure 1:

- For Figure 1 the rate is in terms of injury crashes per 100 million vehicles, and for the equation the rate is in injury crashes per year through the curve
- The design speed of the curve should be determined from a standard design reference
- The approach speed to the curve is the estimated 85th percentile speed at a point prior to slowing for the curve (for longer tangents this would approximate the speed environment).

Figure 1: Injury crashes per 100 million vehicles for rural curves for type B, C, and D crashes (2015)



3.3 Single-lane rural bridges ≥ 80km/h

The typical crash rate (reported injury crashes per year) of a single-lane bridge on a rural road (≥ 80km/h) is determined by the equation:

$$A_T = b_0 X$$

where: X is the exposure in 100 million vehicles crossing the bridge per year

$b_0 = 8.7 (Q_T)^{0.3}$ (2015 analysis year)

Q_T is the two-way daily traffic volume (AADT)

This equation does not take into account low design speed approach curves (65km/h advisory speed or less), traffic signal control or adjoining intersections within 200 metres of the bridge.

3.4 Two-lane rural bridges, ≥ 80km/h

The typical crash rate (reported injury crashes per year) of a two-lane bridge on a rural road (≥ 80km/h) is determined by the equation:

$$A_T = b_0 X$$

where: X is the exposure in 100 million vehicles crossing the bridge per year

$b_0 = 0.83 \times c \times (0.5 - 0.25\ RW + 0.025\ RW^2)$ (2015 analysis year)

With RW being the difference between the seal width across the bridge and the total sealed lane width in metres (both directions) on the bridge approaches (normally 7 metres on state highways). A narrow bridge seal width leads to a negative value for RW. The limits of RW are governed by the limiting width for single-lane operation (for the maximum negative value of RW) and 2.5 metres (maximum positive value of RW). The value of c is given by the formula:

$$c = e^{(3.5 - QT / 7,500)}$$

where: Q_T is the two-way daily traffic volume (AADT)

This model does not take into account low design speed approach curves (65km/h advisory speed or less) or adjacent intersections within 200 metres of the bridge. In this situation the combined effects of different road elements (bridge, curve and intersection) can be greater or less than the effects of that predicted using the various crash rates and crash prediction models for each road element. The use of crash history through the weighted crash analysis procedure can enable the combined crash effect to be better understood, although the crash history in turn is heavily influenced by the random occurrence of injury crashes.

In the weighted crash procedure, use the k-values provided in Table 6**Error! Reference source not found.**.

Table 6: Rural bridge type k values

Rural bridge type	k value
Single-lane bridge	0.3
Two-lane bridge	0.2

4.0 Urban Roads (≤ 70 km/h)

Crash prediction models are available for all injury crashes on urban mid-blocks and for pedestrian and cyclists involved in injury crashes at mid-blocks. Crash prediction models for urban intersections are found in Sections 7 and 8.

4.1 Urban mid-block – injury crashes

Crash prediction models are used to estimate total injury crashes at urban midblock sites. The typical crash rate (reported injury crashes per year) is dependent on roadside development. Separate pedestrian and cyclist models are also available. All reported injury crashes are calculated using the model:

Injury crashes per year = $b_0 \times Q^{b_1} \times L \times \sum CMFs$

$\sum$Crash Modifying Factor (CMF) = $CMF_1 * CMF_2 * \ldots$ (e.g. solid and flushed medians)

Where:
- b_0 and b_1 = model parameters (Table 7)
- Q = annual average daily two-way traffic volume
- L = length (kilometres)

Table 7: Urban mid-block land-use coefficients

Land-use	Commercial		Other	
Mid-block road type	b_0	b_1	b_0	b_1
Access (Local)	2.19×10^{-4}	0.98	2.19×10^{-4}	0.98
Primary and Secondary Collectors	2.99×10^{-5}	1.08	2.99×10^{-5}	1.08
National and Regional Strategic and Arterial (2 and 4 lane)	6.63×10^{-6}	1.20	1.16×10^{-4}	0.88

Table 8 shows the traffic volume range over which the crash prediction models should be applied and also the 'k' values to use in economic evaluation (using Method C). There is less certainty in crash estimation when a route has a traffic volume outside this flow range.

Table 8: Urban mid-block land-use k values

Mid-block type	Speed limit	Flow range AADT	k value	
			Commercial	Other
Access (Local)	50km/h	< 3,000	0.6	0.6
Primary and Secondary Collectors	50km/h	2,000 – 8,000	10.0	10.0
National and Regional Strategic and Arterial (2 and 4 lane)	50 or 60km/h	3000 – 24,000	8.5	10.8

There is currently no New Zealand information available for six or more lane arterials. Six-lane roads are likely to have a greater proportion of weaving-related crashes, particularly where intersections are closely spaced.

4.2 Urban mid-block – pedestrian and cyclist crashes

Pedestrian and cyclist crash prediction models are provided for estimating injury crashes that involve crossing pedestrians and through cyclists on road mid-block (Table 9). These models can be used to assess the benefits of a new or improved pedestrian or cyclist facility by applying a CMF. These models are for urban (speed limit <80km/h) areas and do not include any pedestrian or cyclist crashes that occur at side roads. However, driveway crashes are included. The number of reported injury crashes per year for each crash type is calculated using the models in Table 10.

Table 9: Urban mid-block – Pedestrian and Cyclist crash variables and CAS movement categories

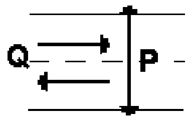
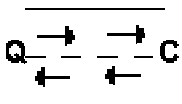
Crash types	Variables	CAS movement categories
All mid-block pedestrian crashes	Q = Two-way vehicle flow in veh/day P = Pedestrian crossing volume per 100 metres in ped/100m/day L = Segment length in km 	NA-NO, PA-PO
All mid-block cyclist crashes	Q = Two-way vehicle flow in veh/day C = Two-way cycle flow in veh/day/100m L = Segment length in km 	All

Table 10: Urban mid-block – pedestrian and cyclist facilities models (model references 6 and 16).

Crash types	Model	k value (mid-point)
All mid-block pedestrian crashes	$A_T = 1.27 \times 10^{-4} \times Q^{0.69} \times P^{0.26} \times L$	-
All mid-block cyclist crashes	$A_T = 2.36 \times 10^{-4} \times Q^{0.84} \times L^{0.30} \times$ No_Parking (Parking = 1 and No_Parking = 0.25)	-

5.0 Multi-lane High Speed Roads (including Motorways)

The typical two-way crash rate (reported injury crashes per year) for 4-lane motorways and four-lane divided rural roads is calculated using the model:

$$A_T = b_0 \times Q_T^{b_1} \times L$$

where: Q_T is the daily two-way traffic volume (AADT) on the link

L is the length of the motorway link

b_0 and b_1 are given in Table 11

The main difference between crash rates on four-lane divided rural roads and four lane motorways is the presence of at-grade intersections and accesses and on some routes cyclists. In New Zealand the mid-block crash rates for motorways and four lane divided roads are similar. Hence a single crash prediction model for mid-blocks can be used for both. When assessing four-lane divided roads additional analysis is required to predict the crash risk associated with at-grade intersection and accesses (using intersection models) and bicycles.

An analysis of crash rates on motorways and four-lane divided roads indicates that the crash rate typically varies between 3 and 11 crashes per 100 million vehicle kilometres, with most being under 9. The exception is on 6+ lane motorways and motorway sections with steep grades (often with climbing lanes), where in some cases the rates exceed 11.

Table 11 shows the model parameters. The b_1 value is much greater than 1 indicating that the rate of injury rates per vehicle increases as traffic volumes (and number of lanes) increase. This explains the higher rates found on motorways with more than four lanes, including the addition of climbing lanes. A similar result has been found in a number of other countries. This increase is likely to be due to an increase in lane changing and also traffic congestion in peak periods on the higher volumes motorway sections.

Table 12 shows the range of one-way flows over which the crash prediction models should be applied and the k values for use in the weighted crash procedure.

Table 11: Four-lane divided rural roads coefficients

	b_0	b_1
Motorway and four-lane divided roads.	2.56×10^{-7}	1.45

Table 12: Four-lane divided rural roads k values

	Flow range AADT	k value
Motorway and four-lane divided roads.	15,000 – 68,000	10.2

Motorway link crash prediction models are also available by crash type in Turner (2001). New Zealand crash prediction models are not currently available for motorway interchanges and other grade-separated intersections. Interchange models are available for a variety of different interchange layouts, including motorway to motorway links, in the USA. The USA interchange models are included in the ISAT software that is available through the Federal Highway Authority (FHWA).

Some calibration of the ISAT models has been done for several interchanges. The calibration shows that these models work well for the Auckland motorway network (the USA predictions being a little higher), but less so for other grade separated intersections around New Zealand. It is preferable than using crash rates and models for standard intersections and urban links within this manual. For the Auckland motorway a calibration factor of 0.85 (15% reduction) should be applied to ISAT urban motorway predictions (this factor is based on analysis undertaken in the early 2010's). We recommend caution when using ISAT outside of the Greater Auckland area.

6.0 Intersections – Product of Flow Models

Product of flow models use road link traffic volumes to estimate the number of crashes occurring at cross roads and T-intersections. The typical models used are:

Injury crashes (priority and traffic signals) $= b_0 \times Qmajor^{b1} \times Qminor^{b2} \times \sum CMFs$

Injury crashes (roundabouts) $= b_0 \times Qapproach^{b1} \times \sum CMFs$

∑Crash Modifying Factor (CMF) $= CMF_1 * CMF_2 * \ldots$ (e.g. lighting and splitter island)

Where:

	b_0, b1 and b2	= model parameters
	Qmajor	= annual average daily two-way traffic volume on highest volume road (signals) or priority road
	Qminor	= annual average daily two-way traffic volume on lowest volume road (signal) or side-road
	Qapproach	= annual average daily two-way traffic volume on each roundabout approach
	L	= length (km).

6.1 Urban Priority and Signalised Cross roads and T-junctions 50-70km/h

The 'general' model is suitable for most urban cross roads (four leg) and T-junctions (three leg) types and uses two-way link volumes where the posted speed limit is 50–70km/h. Where a breakdown by crash type and road user type is required, or where the proportion of turning vehicles is high compared with through vehicles, then the appropriate conflicting flow models (in Section 7) should be used.

For urban intersections on the primary road network (excluding roundabouts), the typical crash rate (reported injury crashes per year) is calculated using:

$$A_T = b_0 \times Q_{major}^{b_1} \times Q_{minor/side}^{b_2}$$

where: Q_{major} is the highest two-way link volume (AADT) for cross roads and the primary road volume for T-junctions.

$Q_{minor/side}$ is the lowest of the daily two-way link volumes (AADT) for cross roads and the side road flow for T-junctions

b_0, b_1 and b_2 are given in Table 13.

Table 14 shows the range of flows over which the crash prediction models should be applied. The k values are for use in the weighted crash procedure.

Caution should be exercised when using the prediction models for intersections where opposing approach flows (on Q_{major} or Q_{minor}) differ by more than 25%. In such cases, the conflicting flow models in Section 7 should be used.

Table 13: General cross-road and T-junction urban intersections (50-70km/h) coefficients (reference 21)

Intersection type	b_0	b_1	b_2
Uncontrolled – T	2.19×10^{-3}	0.36	0.19
Priority – cross	1.08×10^{-3}	0.21	0.51
Priority – T	4.89×10^{-5}	0.76	0.20
Traffic signals – cross	2.81×10^{-3}	0.46	0.14
Traffic signals – T	1.31×10^{-1}	0.04	0.12

Table 14: General cross-road and T-urban intersections 50-70km/h k values

Intersection type	Range Q_{major} AADT	Range Q_{minor} AADT	k value
Uncontrolled – T	3000 – 30,000	500 – 4,000	2.6
Priority – cross	5000 – 22,000	1500 – 7000	2.3
Priority – T	5000 – 26,000	1000 – 5000	3.8
Traffic signals – cross	10,000 – 32,000	5000 – 16,000	4.8
Traffic signals – T	11,000 – 34,000	2000 – 9000	4.6

6.2 Urban Roundabouts 50-70 km/h

Often roundabouts do not have the roads with the highest or lowest volumes on opposing arms, or if they have three arms these are seldom in a 'T'. Therefore, crashes are calculated for each arm of the roundabout, and the total obtained by adding these together. The typical crash rate (reported injury crashes per approach per year) is calculated using the model:

$$A_T = b_0 \times Q_{approach}^{b_1}$$

where: $Q_{approach}$ is the two-way link volume (AADT) on the approach being examined.

b_0, and b_1 are given in Table 15.

This model can be applied for roundabouts with three, four or five approaches. Table 16 shows the range of flows over which the crash prediction model should be applied. The k values are for use in the weighted crash procedure.

Table 15: General urban roundabouts 50-70km/h coefficients (reference 5)

Number of entry lanes per approach	Single		Multiple	
	b_0	b_1	b_0	b_1
Roundabout	4.81×10^{-4}	0.58	7.95×10^{-4}	0.58

Table 16: General urban roundabouts 50-70km/h k values

Number of entry lanes per approach	Single		Multiple	
	Flow range AADT	k value	Flow range AADT	k value
Roundabout	170 – 25,000	2.2	800 – 42,000	2.2

6.3 High-speed (Rural) Priority and Signalised Cross roads and T-junctions (≥ 80km/h on main road)

The 'general' model is suitable for most high-speed (rural) cross roads and T-junctions and use two-way link volumes. High speed intersections are those where the speed limit on the main road is 80km/h or greater. The side-road can be any speed limit. Where a breakdown of crashes by crash and road user type is required, or where the proportion of turning vehicles is high compared with through vehicles then conflicting flow models in Section 7 should be used.

For high-speed cross roads and T-junctions, the typical crash rate (reported injury crashes per year) is calculated using the model:

$$A_T = b_0 \times Q_{major}^{b_1} \times Q_{minor/side}^{b_2}$$

where: Q_{major} is the highest two-way link volume (AADT) for cross roads and the primary road volume for T-junctions.

$Q_{minor/side}$ is the lowest of the daily two-way link volumes (AADT) for cross roads and the side road flow for T-junctions.

b_0, b_1 and b_2 are given in

Table 17.

Table 18 shows the range of flows over which the crash prediction models should be applied. The k values are for use in the weighted crash procedure.

Caution should be exercised when using the prediction models for intersections where opposing approach flows (on Q_{major} or Q_{minor}) differ by more than 25%. In such cases, the conflicting flow models in Section 7 should be used.

Table 17: General high-speed cross roads and T-junctions ≥ 80km/h coefficients (reference 8)

Intersection type	b_0	b_1	b_2
Priority – cross	3.74×10^{-4}	0.39	0.50
Priority – T	3.52×10^{-4}	0.18	0.57
Traffic signals – cross	3.15×10^{-4}	0.52	0.19
Traffic signals – T	4.41×10^{-2}	0.37	-0.10

Table 18: General high-speed cross and T-intersections ≥ 80km/h k values

Intersection type	Range Qmajor AADT	Range Qminor AADT	k value
Priority – cross	50 – 24,000	50 – 3500	2.6
Priority – T	50 – 26,000	50-- 9000	4.7
Traffic signals – cross	19,000 – 46,000	11,000 – 20,000	4.7
Traffic signals – T	10,000 – 54,000	1700 – 17,000	2.0

6.4 High-speed (Rural) Roundabouts (≥ 80km/h on main road)

Often roundabouts do not have the roads with the highest or lowest volumes on opposing arms, or if they have three arms these are seldom in a 'T'. Therefore, crashes are calculated for each arm of the roundabout, and the total obtained by adding these together. The typical crash rate (reported injury crashes per approach per year) is calculated using the model:

$$A_T = b_0 \times Q_{approach}^{b1}$$

where: $Q_{approach}$ is the two-way link volume (AADT) on the approach being examined.

b_0, and b_1 are given in Table 19.

This model can be applied for roundabouts with three or four approaches. Table 20 shows the range of flows over which the crash prediction model should be applied. The k values are for use in the weighted crash procedure.

Table 19: High-speed roundabout coefficients (reference 8)

	b_0	b_1
Roundabout	4.33×10^{-4}	0.53

Table 20: High-speed roundabout k values

	Flow range AADT	k value
Roundabout	800 – 29,000	2.1

6.5 Urban and Rural Railway Crossings

For urban and rural railway crossings, the typical crash rate (reported injury hit train and rear-end crashes per year) is calculated using the model:

$$A_T = b_0 \times T^{b1} \times Q_T^{b2}$$

where: T is the number of trains per day

Q_T is the daily two-way traffic volume (AADT)

b_0, b_1 and b_2 are given in

Table 21

Table 22 shows the range of traffic volumes and trains over which the crash prediction models should be applied. The k values are for use in the weighted crash procedure.

A large number of railway crossings are located in close proximity to low design speed curves. Low design speed approach curves are often caused by the route having to deviate sharply when crossing the railway line. In such circumstances separate predictions of the typical crash rates on these approach curves need to be made using the model for rural isolated curves (≥ 80km/h). Analysts should be aware that the combined crash rate for both the railway crossing and approach curves may be different than the sum of the two element predictions. In such cases the weighted crash analysis procedure can be useful as the actual crash history is also used in the calculation of the crash rate.

Table 21: Urban and rural railway crossings coefficients

Control type	b0	b1	b2
Half-arm barriers	4.18×10^{-4}	0.27	0.33
Flashing lamps and bells	6.22×10^{-4}	0.61	0.32
No control	1.44×10^{-3}	0.31	0.36

Table 22: Urban and rural railway crossings k values

Control type	Traffic volumes		k value
	Q_T AADT	Trains AADT	
Half-arm barriers	<13,000	<40	1.8
Flashing lamps and bells	<6000	<30	0.7
No control	<1000	<20	2.7

7.0 Intersections - Conflicting Flow Models

Conflicting flow models provides a breakdown of the predicted crashes by road user type (e.g. pedestrian and cyclists) and crash type (refer to Appendix A). Crash type models are usually only available for the major crash types at each intersection. The total number of injury crashes at an intersection is calculated by adding up the crashes by each type and approach and then using either a general/other crash prediction model or a factor to take into account the crashes not modelled.

Conflicting flow models are typically used in analysis when there are a high proportion of vehicles making turning movements, especially right turns and when treatments impact on particular crash types or crash modes. Examples of the latter include installing a right turn bay at a rural priority intersection and right turn signal phasing at urban traffic signals.

There is no general model form for conflicting flow models. Some include only flows while others have many other variables. The sections that follow demonstrate the models that are available for each intersection type.

7.1 Urban signalised crossroads <80km/h

There have been several research studies in New Zealand that have developed crash prediction models for urban traffic signals. This varies from very basic product-of-flow models (as in Section 6) through to detailed models with a large number of variables for each road user type, by city (across New Zealand) and by time of day (e.g. morning and evening peaks). In this case 'national models' by key crash type for each transport model (motor-vehicles, pedestrians and cyclists) have been presented. For more detailed analysis by city type, day of week or for more complex intersections it is recommended that analysts utilise the models provided in the various research studies of traffic signals listed in the reference section (in particular reference 18).

The conflicting flow models for signalised crossroads are suitable for situations where a breakdown of crashes by crash and road user type is required, or where the proportion of turning vehicles is high compared with through vehicles. For urban (speed limit <80km/h) signalised crossroads on the primary road network the typical crash rates can be calculated for the six crash types (13, 19) in Table 23. The number of reported injury crashes per year for each crash type on each approach can be calculated using the models in

Table 24. These models calculate the number of crashes per approach and therefore must be used for each approach to the intersection for which the crash type can occur (e.g. at signalised cross roads the crossing (HA) and right-turn-against (LB) crash types shown can occur on all four approaches).

Table 23: Urban signalised cross roads (<80km/h) variables and CAS movement categories

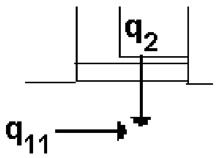
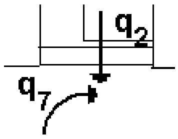
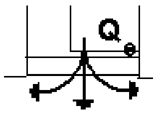
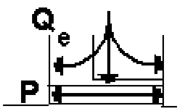
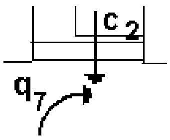
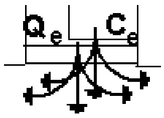
Crash types	Variables	CAS movement categories
Crossing (no turns, motor vehicle only)	$q_{2/11}$ = Through vehicle flows in veh/day 	HA
Right turn against (motor-vehicle only)	 q2 = Through vehicle flow in veh/day q7 = Right-turning vehicle flow in veh/day	LA, LB
Others (motor-vehicle only)	 Qe = Entering vehicle flow in veh/day	-
Pedestrian versus motor vehicle	 Qe = Entering vehicle flow in veh/day P = Pedestrian crossing volume in ped/day	NA-NO, PA-PO
Right turn against (cyclist travelling through)	 q7 = Right-turning vehicle flow in veh/day c2 = Through cycle flow in cyc/day	LA, LB
Others (cyclist versus motor vehicle)	 Qe = Entering vehicle flow in veh/day Ce = Entering cycle flow in cyc/day	-

Table 24: Urban signalised crossroads (<80km/h) crash prediction models (reference 6 and 16)

Crash types	Model	k value
Crossing (no turns, motor vehicle only)	$A_T = 9.17 \times 10^{-5} \times q_2^{0.36} \times q_{11}^{0.38}$	1.1
Right turn against (motor vehicle only)	$A_T = 5.61 \times 10^{-5} \times q_2^{0.49} \times q_7^{0.42}$	1.9
Others (motor vehicle only)	$A_T = 2.12 \times 10^{-4} \times Q_e^{0.59}$	5.9
Pedestrian versus motor vehicle	$A_T = 2.79 \times 10^{-2} \times Q_e^{-0.05} \times P^{0.03}$	1.4
Right turn against (cyclist travelling through)	$A_T = 3.01 \times 10^{-4} \times q_7^{0.34} \times c_2^{0.20}$	1.3
Others (cyclist versus motor vehicle)	$A_T = 1.23 \times 10^{-3} \times Q_e^{0.28} \times C_e^{0.03}$	1.1

7.2 Urban roundabouts (<80km/h)

The conflicting flow models for roundabouts are suitable for situations where a breakdown of crashes by crash and road user type is required, such as roundabouts with high proportions of cyclists. For urban (speed limit <80km/h) roundabouts on the primary road network the typical crash rates can be calculated for the seven crash types (15) in Table 25. The number of reported injury crashes per year for each crash type on each approach can be calculated using the models in

Table 26. These models calculate the number of crashes per approach and therefore must be applied at all approaches to the roundabout.

Table 25: Urban roundabouts (<80km/h) variables and CAS movement categories

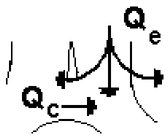
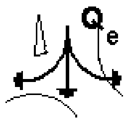
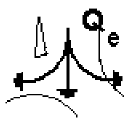
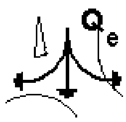
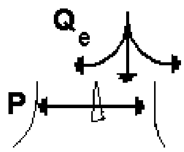
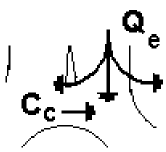
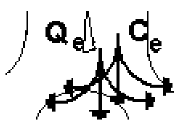
Crash types	Variables		CAS movement categories
Entering-vs-circulating (motor-vehicle only)		Q_e = Entering vehicle flow in veh/day Q_c = Circulating vehicle flow in cyc/day S_c = Mean free speed of circulating vehicles	HA, JA-JO KA-KO, LA-LO
Rear-end (motor-vehicle only)		Qe = Entering vehicle flow in veh/day	FA-FO, GA, GD
Loss-of-control (motor-vehicle only)		Qe = Entering vehicle flow in veh/day V10 = Visibility 10 metres back from the limit line to vehicles on the approach to the right	CA-CO, DA-DO, AD, AF
Other (motor-vehicle only)		Qe = Entering vehicle flow in veh/day	-
Pedestrian		Qe = Entering vehicle flow in veh/day P = Pedestrian crossing volume in ped/day 	NA-NO, PA-PO
Entering-vs-circulating (cyclist circulating)		Qe = Entering vehicle flow in veh/day Cc = Circulating cycle flow in cyc/day Se = Mean free speed of entering vehicles	HA, JA-JO KA-KO, LA-LO
Other (cyclist)		Qe = Entering vehicle flow in veh/day Ce = Entering cycle flow in cyc/day	-

Table 26: Urban roundabouts (<80km/h) crash prediction models (reference 5)

Crash types	Model	k value
Entering-vs-circulating (motor-vehicle only)	$A_T = 6.12 \times 10^{-8} \times Q_e^{0.47} \times Q_c^{0.26} \times S_c^{2.13}$	1.3
Rear-end (motor-vehicle only)	$A_T = 9.63 \times 10^{-2} \times Q_e^{-0.38} \times e^{0.00024 \times Q_e}$	0.7
Loss-of-control (motor-vehicle only)	$A_T = 6.36 \times 10^{-6} \times Q_e^{0.59} \times V_{10}^{0.68}$	3.9
Other (motor-vehicle only)	$A_T = 1.34 \times 10^{-5} \times Q_e^{0.71} \times \Phi_{MEL}$ Φ_{MEL} = 2.66 (if multiple entry lanes) Φ_{MEL} = 1.00 (if single entry lane)	-
Pedestrian	$A_T = 3.14 \times 10^{-4} \times P^{0.60} \times e^{0.000067 \times Q_e}$	1.0
Entering-vs-circulating (cyclist circulating)	$A_T = 3.88 \times 10^{-5} \times Q_e^{0.43} \times C_c^{0.38} \times S_e^{0.49}$	1.2
Other (cyclist)	$A_T = 2.07 \times 10^{-7} \times Q_e^{1.04} \times C_e^{0.23}$	-

7.3 Urban Priority T-junctions (<80km/h on main road)

The conflicting flow models for priority T-junctions in urban areas are suitable for situations where a breakdown of crashes by major crash type is required. Currently crash models are only available for the two main crash types which are 1) Crossing vehicle turning (JA crashes) and 2) Right turn against (LB crashes). The predictions from these models should be treated with caution until further research explores in more detail the new design variables introduced in the design index. The models are provided in

Table 27 with parameters in Table 28.

Table 27: Urban priority T-junctions (<80km/h on main road) variables

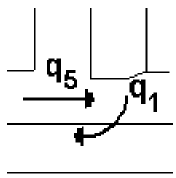
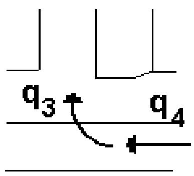
Crash types	Variables	CAS movement categories
Crossing – vehicle turning (major road approach to right of side road)	q_5 = Through vehicle flow along major road to right of minor road vehicles in veh/day q_1 = Right-turning flow from minor road in veh/day MRSL = main road (through road) speed limit DI = Design Index, as defined in Table 28  	JA
Right turn against (motor-vehicle only) –	 q4 = Through vehicle flow in veh/day q3 = Right-turning vehicle flow in veh/day MRSL = main road (through road) speed limit DI = Design Index, as defined in Table 28	LA, LB

Table 28: Urban priority T-junction (<80km/h on main road) models

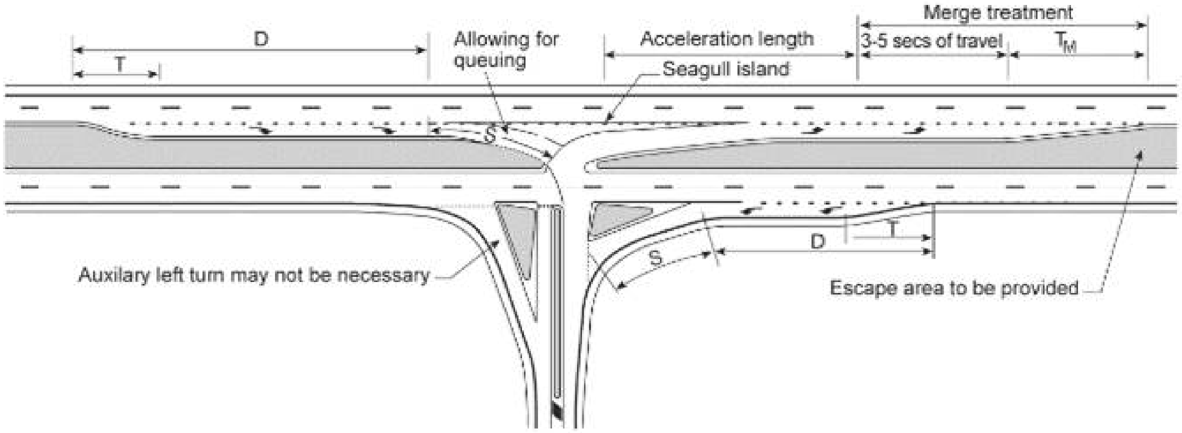
Crash types	Model	k value
Crossing – Vehicle turning (major road approach to right of side road)	$A_T = 1.96 \times 10^{-17} \times q_1^{0.025} \times q_5^{0.13} \times MRSL^{3.80} \times DI^{5.8}$ DI = (0.88*RTBTL+6.49*(6-MRMW)+17.86*NSNTL + 1.50*(19-4*DFSUF)+30.30*(7-2*SRNL)+1.41*(4*SRMW+1)+7.69*(2*GMRRS-1)+18.52*(6-UMIT)+1.53*(19-4*WAL)+2.15*(19-4*CP))/10	50
Right Turn Against	$A_T = 3.35 \times q_3^{0.40} \times q_5^{0.21} \times MRSL^{-4.53} \times DI^{3.07}$ DI = (2.11*(4*DNSUF-1)+11.98*(3-SRMI)+15.87*SRMW+2.14*(4*SL-1)+24.69*TTCB+9.00*(4*UMIW-1)+8.55*WDL+0.88*TMRW)/8	50

Where the variables in the two design indices (DI) are as follows:

- RTBTL – Right turn bay taper length (in metres).
- MRMW – Main Road Median width. Equals 1 for painted line, 2 when median <0.5m, 3 when between 0.5 and 1m, 4 when between 1 and 2m and 5 when >2m.
- NSNTL – Near side number of through lanes. Equals 1 for one lane or 2 for two lanes.
- DFSUF – Distance to far side upstream feature (to left of side-road). Equals 1 when distance is 0-49m, 2 when 50 to 99m, 3 when 100m to 199m and 4 when 200m plus.
- SRNL – Side road number of lanes. Equals 1 for left turn & right turn, 2 for left-right stacked side by side in single lane and 3 for combined left and right in one lane.
- SRMW – Side Road Median width. Equals 1 if no centreline, 2 if painted line, 3 if <0.5m width, 4 if between 0.5 and 1m, 5 if between 1 and 2m and 6 if >2m.
- GMRRS – Gradient of main road, right side. Equals 1 if flat, 3 if moderate and 5 if steep.
- UMIT – Upstream median island type. Equals 1 for painted line, 2 for hit posts, 3 for solid barrier, 4 for painted island and 5 for solid island.
- WAL – Width of acceleration lane (in metres).
- CP – Car parking. Equals 1 for none, 2 for one of three sides, 3 for two of three sides and 4 for three (or all) of three sides.
- DNSUF – Distance to near side upstream feature (to right of side-road). Equals 1 when distance is 0-49m, 2 when 50 to 99m, 3 when 100m to 199m and 4 when 200m plus.
- SRMI – Side road median island. Equals 1 when present, 2 when not present.
- SL – Street lighting. Equals 1 when none, 2 when one at the top of T-Junction, 3 when one at the side of approach road and 4 when full.
- TTCB – Top of T-junction chevron board. Equals 1 when present, 2 when not present.
- UMIW – Upstream median island width. Equals 1 when <0.5m, 2 when 0.5m-1m, 3 when 1m-2m and 4 when >2m.
- WDL – Width distraction to left. Equals 2 when none present and 4 when present (e.g. bus stop).
- TMRW – Total main road width (in metres).

Seagull Layouts

Crash Prediction Models are also available for priority tees with seagull shaped intersections (as shown below) with either painted or raised islands. The Seagull models include LTSLs. The performance of Seagull layouts depends on the design of the intersection. Research indicates that well designed Seagulls have a good safety record.



Seagull intersection treatments are rarely used in New Zealand in part due to poor road safety experience at a number of such intersections in the past. There are however locations where seagulls are an ideal treatment in terms of improving efficiency and due to their relatively low construction costs, compared to other options. They are popular in urban areas where site constraints do not permit a roundabout or traffic signals to be built. Recent research has indicated that seagulls can be safer in some situations than traditional T-intersections, but only if designed correctly.

Some of the Key design factors that need to be avoided:

A. Locating such intersections on moderate to sharp bends or on crests and dips especially when it is difficult for drivers to read the intersection layout.
B. Four or more lanes with high traffic flows, due to difficulties picking a gap in traffic and there is two lanes to cross before the safety of the central median.
C. Where the speed limit is high (greater than 60km/h) and/or the right turn out movement is high.
D. On wide median roads where the right-turn-in lane is between a 15 and 45 degree angle to the through lane. It should be as close as possible to parallel to the through lane, as occurs at traditional painted right turn lanes.
E. There are nearby intersections (including railway crossings and pedestrian crossings), major accesses, parking and busy bus stops or other distractions that may divert drivers attention.

The research indicates that well-designed seagull intersections may perform better than standard, non-chanelised T-intersections (note the long list of variables that can impact on the crash rate). A 'Beta version' spreadsheet calculator has been developed for assessing urban and rural seagull intersections. This is available through the Transport Agency.

7.4 High Speed Priority Cross Roads (≥ 80km/h on main road)

The conflicting flow models for priority crossroads in high-speed areas are suitable for situations where a breakdown of crashes by crash type is required, or where the proportion of turning vehicles is high compared with through vehicles. For high-speed (speed limit ≥ 80km/h on main road) priority cross roads on two-lane, two-way roads the typical crash rates can be calculated for the five crash types in Table 29. The number of reported injury crashes per year for each crash type is calculated in Table 30: These models calculate the number of crashes per approach for both 'major road' and 'minor road', with the minor road being the road with stop or give way control.

Table 29: High speed priority cross roads (≥ 80km/h on main road) variables

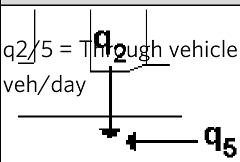
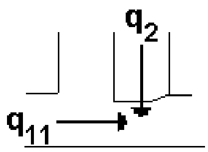
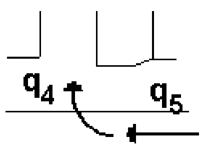
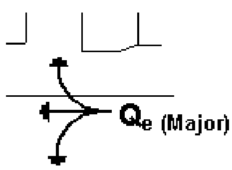
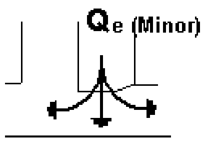
Crash types	Variables	CAS movement categories
Crossing – hit from right (major road approaches only)	q2/5 = Through vehicle flows in veh/day 	HA
Crossing – hit from right (minor road approaches only)	q2/11 = Through vehicle flows in veh/day 	HA
Right turning and following vehicle (major road approaches only)	q5 = Through vehicle flow along major road in veh/day q4 = Right-turning flow from major road in veh/day 	GC, GD, GE
Other (major road approaches only)	Qe = Entering vehicle flow on major road in veh/day 	-
Other (minor road approaches only)	 Qe = Entering vehicle flow on minor road in veh/day	-

Table 30: High speed priority cross roads (≥ 80km/h on main road) models (reference 8)

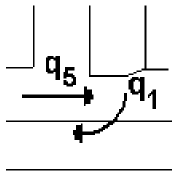
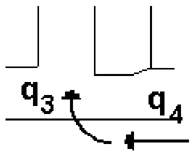
Crash types	Model	k value
Crossing – hit from right (major road approaches only)	$A_T = 1.2 \times 10^{-4} \times q_2^{0.60} \times q_5^{0.40}$	0.9
Crossing – hit from right (minor road approaches only)	$A_T = 2.05 \times 10^{-4} \times q_2^{0.40} \times q_{11}^{0.44}$	2.0
Right turning and following vehicle (major road approaches only)	$A_T = 1.08 \times 10^{-6} \times q_4^{0.36} \times q_5^{1.08} \times \Phi_{RTB}$ $\Phi_{RTB} = 0.22$ (if right-turn bay present) $\Phi_{RTB} = 1.00$ (if right-turn bay absent)	2.6
Other (major road approaches only)	$A_T = 1.14 \times 10^{-4} \times Q_{e(Major)}^{0.76}$	1.1
Other (minor road approaches only)	$A_T = 3.44 \times 10^{-3} \times Q_{e(Minor)}^{0.27}$	0.2

7.5 High-speed priority T-junctions (≥ 80km/h on main road)

The conflicting flow models for priority T-junctions in high-speed areas are suitable for situations where a breakdown of crashes by crash type is required, where one turning movement from the side road is greater than the other, or where the intersection has a visibility and other design deficiencies. For high-speed (speed limit 80km/h on main road) priority T-junctions on two-lane and four-lane, two-way roads the typical crash rates can be calculated for the five crash types in Table 31.

The typical crash rate (number of reported injury crashes) per year for each crash type is calculated using Table 32. Two models are provided for the first crash type, crossing – vehicle turning. The first model (which includes measured approach speed, rather than speed limit, and multiple design factors) is the preferred model, as it was developed more recently. The second model has been included for situations were visibility may be an issue and where approach speed and many of the design variables are not available. Unlike models for other intersections, these models are each for a specific approach.

Table 31: High speed priority T-junctions (≥ 80km/h on main road) variables

Crash types	Variables	CAS movement categories
Crossing – vehicle turning (major road approach to right of side road)	q5 = Through vehicle flow along major road to right of minor road vehicles in veh/day q1 = Right-turning flow from minor road in veh/day VD = Sum of visibility deficiency in both directions when compared with Austroads SISD (3). Note: if there is no visibility deficiency then a default value of 1 should be used for VD MRAS = main road (through road) approach speed (measured) DI = Design Index, as defined in Table 32  	JA
Right-turning and following vehicle (major road approach to left of side road)	q5 = Through vehicle flow along major road to right of minor road vehicles in veh/day q3 = Right-turning flow from major road in veh/day SL = Mean free speed of vehicles approaching from the left of vehicles minor road  	GC, GD, GE

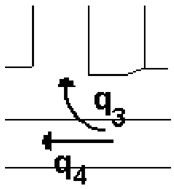
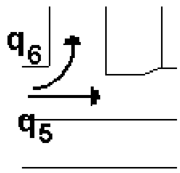
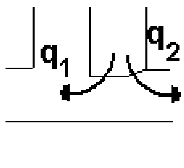
Other (major road approach to left of side road)	q5 = Through vehicle flow along major road to right of minor road vehicles in veh/day q3 = Right-turning flow from major road in veh/day 	-
Other (major road approach to right of side road)	q5 = Through vehicle flow along major road to left of minor road vehicles in veh/day q6 = Left-turning flow from major road in veh/day 	-
Other (side road approach)	q1 = Right-turning flow from minor major road in veh/day q2 = Left-turning flow from minor road in veh/day 	-

Table 32: High speed priority T-junction (≥ 80km/h on main road) models (reference 8)

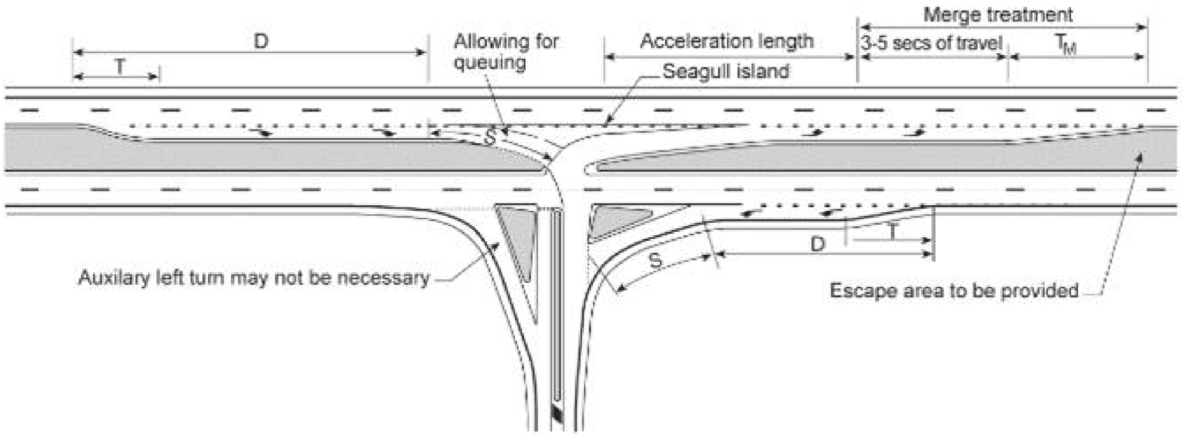
Crash types	Model	k value
Model 1 for Crossing – Vehicle turning (major road approach to right of side road)	$A_T = 6.46 \times 10^{-14} \times q_1^{0.51} \times q_5^{0.27} \times MRAS^{3.97} \times DI^{1.58}$ DI = (34.48*(6-2*RTB)+90.91*(2*LWRTMR-3)+22.32*RTBS+20*(4-2*MRMW)+45.45*(PNSUF + 3)+11.49*(17/3-4*RTAVLL))/6	50
Model 2 for Crossing – Vehicle turning (major road approach to right of side road)	$A_T = 4.39 \times 10^{-6} \times q_1^{1.33} \times q_5^{0.15} \times V_D^{0.33}$	8.1
Right-turning and following vehicle (major road approach to left of side road)	$A_T = 4.39 \times 10^{-27} \times q_3^{0.46} \times q_4^{0.67} \times S_L^{11}$	0.2
Other (major road approach to right of side road)	$A_T = 1.32 \times 10^{-5} \times (q_5 + q_6)^{0.91}$	1.0
Other (major road approach to left of side road)	$A_T = 2.48 \times 10^{-4} \times (q_3 + q_4)^{0.51}$	3.0
Other (side road approach)	$A_T = 1.22 \times 10^{-2} \times (q_1 + q_2)^{-0.02}$	0.6

Where the variables in the design index (DI) are as follows:

- RTB – Right turn bay. Equals 1 if Yes and 2 if No.
- LWRTMR – Lane width of right turn from main road (in metres).
- RTBS – Right turn bay stacking. Equals number of vehicles, assuming one vehicle = 6m.
- MRMW – Main road median width. Equals 0 when none, 1 when a painted line, 2 when <0.5m, 3 when 0.5m to 1m, 4 when 1m to 2m and 5 when >2m.
- PNSUF – presence of a near-side (side-road side) upstream feature (to right of intersection). Equals +1 if Yes and -1 if No.
- RTAVLL – Right approach visibility two metres from limit line (in metres).

Left Turn Slip Lanes and Seagull Layouts

Crash Prediction Models are also available for priority tees with a left turn slip lane (LTSL) into the side-road and for seagull shaped intersections (as shown below) with either painted or raised islands. The Seagull models include LTSLs. In rural and high speed areas we recommend use of raised seagull islands. The performance of LTSLs and Seagulls layout depends on the design of the intersection. Research indicates that in some situations well designed LTSL and Seagulls have a good safety record.



Left Turn Slip Lanes (LTSLs)

LTSL are commonly used to improve the efficiency of priority controlled intersections, by providing an area/lane of various dimensions for vehicles to decelerate within when turning left into a side-road. While they may reduce the likelihood of relatively rare rear-end crashes involving through and left turning traffic some designs do appear to increase the risk of the more severe and common crash type involving vehicles turning right out of the side-road being hit by through vehicles from there right ('JA' crashes). Problems occur when the left turners block the visibility to following through vehicles on the through lane(s). The location of the side-road limit line, and hence location of driver, the volume of left turners and the design of the LTSL has an impact on these crashes. The crash risk can vary by time of day depending on the various turning movement volumes.

Best practice is to either 1) start the left turn lane early and provide a painted or raised island that create adequate separation of through and left turn lanes so that right turn out drivers can clearly see the through traffic or 2) provided a short left turning area close to the intersection such that through vehicles are unable to overtake left turners (see figures below). For 2 through lanes we recommend use of option 1 only. At well-designed intersections research indicates that crash reduction of 50% or more can be achieved for LTSLs. A 'Beta version' spreadsheet calculator has been developed for assessing rural LTSLs. This is available through the Transport Agency.

Example of LTSL separation (a) and late LTSL (b)

<u>Seagull (Chanelised) Treatments</u>

Seagull intersection treatments are rarely used in New Zealand in part due to poor road safety experience at a number of such intersections in the past. There are however locations where seagulls are an ideal treatment in terms of improving efficiency and due to their relatively low construction costs, compared to other options. For example, they are popular on higher speed two to four-lane divided highways where side-road volumes are low. Recent research has indicated that seagulls can be safer in some situations than traditional T-intersections, but only if designed correctly.

Key design factors that need to be avoided:

F. Locating such intersections on moderate to sharp bends or on crests and dips especially when it is difficult for drivers to read the intersection layout.
G. Four or more lane roads where the left turning vehicles on main road obstruct the visibility for right turn out drivers of through vehicles. This can be addressed by a suitable LTSL design.
H. Where the right turn out movement is high (greater than 400 vehicles per day)
I. On wide median roads where the right-turn-in lane is between a 15 and 45 degree angle to the through lane. It should be as close as possible to parallel to the through lane, as occurs at traditional painted right turn lanes.
J. There are nearby intersections or other distractions (e.g. commercial land-use) that may divert drivers attention.

The research indicates that well-designed seagull intersections may perform better than standard, non-chanelised T-intersections. A 'Beta version' spreadsheet calculator has been developed for assessing urban and rural seagull intersections. This is available through the Transport Agency.

8.0 Crash modification factors

8.1 Introduction

The following section provides average crash modification factors for treatments or improvements in urban and rural areas. These modifications can be applied to the crashes and crash rate calculated using any of the three crash analysis methods. Key references for CMF and CRF include Austroads (7), and The Handbook of Road Safety Measures (2). Before and after New Zealand studies of treatments have also been included. Other international sources of CMFs and CRFs include the Highway Safety Manual (22), and the CMF Cleaning house (23)

A CMF's / CRF's typical area of influence of intersections extends 50 metres along each leg, and similarly an area of influence 50 metres from either side of a bridge and railway crossing should generally be adopted. However, analysts are cautioned that at some sites the area of influence can be affected by vehicle speeds, and road geometry. Judgement is also required to assess when the effect of a CMF may extend beyond the area of treatment (for example passing lanes). In rural areas, crash migration should also be considered; this issue is explained in more detail within Appendix A6.

The modification factors are only a guide to possible modification rates and the evaluation documentation will need to substantiate all claimed crash modifications, particularly if they are expected to be greater than indicated here.

Relative confidence level categories of low, medium and high have been assigned to each treatment. The confidence level is based upon the level, location, date, and type of research available to corroborate the CMF/CRF. A low level of confidence may also indicate that the benefit can range significantly depending on the environment in which it is applied. We would recommend that users perform sensitivity analysis when there are low levels of confidence in the CMF/CRF particularly when most of the project benefits are from such treatments. In such circumstances the use of more localised research on the project location may also be valid.

8.2 Typical crash reductions

The following tables (Table 33 to

Table 38) provide a typical range of injury crash modification factors (CMFs) and crash reduction factors (CRFs) for mid-block and intersection treatments. The tables are ordered to correspond with each crash model type; rural mid-blocks and motorways, urban mid-blocks, and product of flow intersection models (urban and rural). The crash modifying factors should be applied to total crash predictions for each intersection and mid-block length. (where CMFs are available). CMFs cannot be used for specific crash types e.g. as predicted by conflicting flow models) or for other crash subcategories (e.g. night crash). They are however provided for total pedestrian and cyclist crash predictions where relevant.

For crash prediction models by conflict type key non-flow factors are usually included with crash prediction models. Some treatments such as delineation are common to several site environments and are shown under each model where commonly used. Treatments for cyclists and pedestrians transcend all models and are shown separately.

When there is more than one measure the CMFs should be multiplied together.

CRFs are provided by crash type and crash sub-category (e.g. night) where the treatment impacts on a specific crash type. CRFs are provided for crash-by-crash analysis.

When using multiple CRFs for each crash type it is not appropriate to add all of the reduction factors together. In these cases judgement should be exercised in determining the likely overall effectiveness of multiple measures on each crash type.

Table 33: Common rural midblock crash reduction/modification factors

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install overtaking lanes		25% All crashes	0.75	Low	Reduce these crashes linearly to zero for crashes following the passing lane up to 5km away. Ensure loss of control crashes do not increase due to design.
		50% of head-on crashes	N/A	Low	
		30% of overtaking crashes.	N/A	Low	
Install no overtaking markings		35% All crashes	0.65	Medium	Where no-overtaking lines missing and are required due to poor visibility
		50% of head-on crashes	N/A	Medium	
		40% of overtaking crashes	N/A	Medium	
Install edge-line		10%	0.9	Low	
Install centreline		20%	0.8	Low	

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
Install rural wide centreline (NEW - described in HRRRG)		20% of all injury crashes	*0.80*	*Low*	Wide centrelines are particularly effective at reducing deaths and serious injuries and head-on and run-off road crashes where traffic volumes are greater than 14,000 vpd. Care should be taken applying this treatment at locations with high numbers of intersection and 'other' crash types and where volumes are less than 14,000 vpd.
		40% of cross centreline crashes	N/A	Low	
Edge-line and centreline combination (NEW)		30%	0.7	Low	
Painted speed limits (NEW)		0%	1	Low	A 0% crash reduction factor is allocated based on conflicting overseas research, and the lack of effect detected in the Australasian context.
Provide traverse rumble strips (NEW)		25%	0.75	Low	Traverse rumble strips are rarely used in New Zealand. They are only applicable in a few locations. Before trialing this measure please contact the NZ Transport Agency.
Install edge marker posts		5% of all injury crashes	0.95	Low	Edge marker posts are more effective on curves than on straight sections of road. They are normally applied at the same time or after the installation of centrelines and edge-lines.
		40% of loss-of control on curve crashes	N/A	Low	

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install raised reflective pavement markings (RRPMs)	All	5%	0.95	Low	This reduction applies to centre-line RRPMs. CRFs are not currently available for shoulder RRPM.
Install audio-tactile profiled line markings	Profile edge line	20% of all crashes	0.8	Medium	An increase in bicycle and motorcycle crashes may occur when these users are prevalent in the subject area.
		30% of run-off-road crashes	N/A	Low	
	Profile centre line	15% of all crashes	0.85	Medium	
		30% of head-on crashes	N/A	Low	
Resurfacing of curves		Various			Compare injury crash rate at site with typical crash rate and injury crash rates at other local sites that are considered satisfactory.
Consistent super-elevation on a curve (NEW)		40%	0.6	Low	When super-elevation is very inconsistent on a curve.
Sealing unsealed shoulders (NEW)		30%	0.7	High	Factors are based on typical shoulder widths of greater than 0.75m. Consideration must be given to the impact of increased vehicle speeds that may result and mitigate effects. Widening is likely to be more effective on curves than on straights.

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Sealing gravel road (NEW)		0%	1.0	Low	Can cause an increase in crashes where steep grades and out of context curves are present, due to increased speeds. In such circumstances road improvements are needed to mitigate such hazards (e.g. curve advisory signage).
Install bridge signs (NEW)		30% of crashes associated with bridges	N/A	Low	
Install chevron signs on horizontal curves (NEW)		25% of curve related crashes only	N/A	High	
Speed cameras (NEW)	Mobile overt	40%	0.6	Medium	Where speeding is identified as a problem. Covert speed camera evaluations are typically conducted on an area-wide basis so cannot be compared to overt evaluations which are conducted at or near camera sites. The effectiveness of speed cameras is related to how frequently they are implemented.
	Mobile covert - rural	20%	0.8	Medium	
	Fixed overt – rural	30%	0.7	Low	
Install w-section guardrail (around roadside hazards)		30% of all injury crashes	0.7	High	This CMF only applies over isolated sections of guardrail. For continuous guardrail refer to following CRFs and CMFs.
		40% of all fatalities	N/A	High	
		30% of all serious injury crashes	N/A	High	

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
		10% of all minor injury crashes	N/A	High	
Install continuous combined roadside and median wire rope improvements (NEW)		65% of all injury crashes	0.35	Low	
		80%of all fatal and serious injury crashes	N/A	Low	
Install continuous flexible median barrier (NEW)		50% of all injury crashes	0.5	Low	
		60% of all fatal and serious injury crashes	N/A	Low	
		90% of fatal and serious head on crashes	N/A	Low	
Install continuous flexible roadside barrier (NEW)		15% of all injury crashes	0.85	Low	
		45% of run off road injury crashes	N/A	Low	
		65% of fatal and serious injury run off road crashes	N/A	Low	

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install clear zones to 6 metres where there are significant hazards		35% of loss-of-control crashes	N/A	Low	In many situations roadside barriers (continuous or around hazards) are likely to be more effective than clear-zones.
Install vehicle activated signs (for example speed activated warning signs) (NEW)	All	35%	N/A	Medium	Treatment is typically used near curves, bridges, schools, work-sites, speed limit changes and intersections. Crash reduction applies to crashes associated with site of treatment
Install route lighting	two lane roads (levels V1-V3)	15% of night-time crashes	0.95	High	Crash reduction factor based on night crashes only. CMFs based on 32% of crashes occurring at night. Where there is sufficient evidence (from the crash history) that a site has a higher or lower proportion than this then a site specific CMF should be developed. CRFs for pedestrian crashes are higher than presented here (see Table 36). Research indicates that lighting has very little effect on loss-of-control crashes. Where the majority of crashes at a site are loss-of-control then the installation of lighting will have a much lower crash benefit than indicated by these factors. Lighting luminance levels are as follows (refer to AS/NZ standard 1158.1.1 for further details) V1 >=1.5 cd/m^2 V2 >=1.0 cd/m^2 V3 >= 0.75 cd/m^2 V4 >= 0.50 cd/m^2
	two lane roads (level V4)	12% of night time crashes		Medium	
	dual carriageway (levels V1-V3)	25% of night-time crashes	0.90	High	
	dual carriageway (level V4)	20% of night-time crashes		Medium	

Common rural midblock crash reduction/modification factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
					These factors can be used when upgrading lighting that is below category V4 (i.e. luminance of less than 0.50 cd/m^2).

Table 34: Common urban midblock crash reduction/modification factors

Common Urban Midblock Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Medians	Flush median	15%	0.85	Low	
	Solid median	45%	0.55	Medium	
Parking ban (both sides of the street)	Midblock	20%	0.8	Low	Research indicates that banning parking on one side only may increase crashes.
Parking - convert angle to parallel (NEW)	All environments	40%	0.6	Low	There is a lack of Australasian research on this treatment and there is a significant discrepancy between the results. Hence, this is only an indication of the likely level of crash reduction that could be expected from this treatment.
Road diet: Four lanes to two lanes plus flush median	All	35%	0.65	Low	

Common Urban Midblock Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
New route Lighting	New route lighting to: -Subcategory V4 -Subcategory V3 -Subcategory V2 / V1	 20% 30% 40% of night-time crashes	 0.95 0.91 0.88	 High	Crash reduction factor based on night crashes only. CMFs based on 29% of crashes occurring at night. Where there is sufficient evidence (from the crash history) that a site has a higher or lower proportion than this then a site specific CMF should be developed. CRFs for pedestrian crashes are higher than presented here (see Table 36). Research indicates that lighting has very little effect on loss-of-control crashes. Where the majority of crashes at a site are loss-of-control then the installation of lighting will have a much lower crash benefit than indicated by these factors. Lighting luminance levels are as follows (refer to AS/NZ standard 1158.1.1 for further details) V1 >=1.5 cd/m^2 V2 >=1.0 cd/m^2 V3 >= 0.75 cd/m^2 V4 >= 0.50 cd/m^2 When upgrading lighting from one category to another (e.g. from V4 to V2) then pro rata the factors provided. (e.g. upgrading from V4 to V2 gives a CRF of (1-0.20) x 0.40 = 32%)
	New lighting - railway level crossing (NEW) –V4 to V1	20% of night-time crashes	N/A	High	

Common Urban Midblock Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Traffic calming	All environments	20%	0.8	Medium	Where available use CMFs and CRFs that are specific to each treatment used in traffic calming.
Bus lanes (taxis permitted)	All	25% increase	1.25	Low	There is no Australasian research available on this treatment. This risk may be mitigated by suitable design.
High occupancy vehicle lanes	All	60% increase	1.60	Low	There is no Australasian research available on this treatment. This risk may be mitigated by suitable design.

Table 35: Common Motorway Crash Reduction/Modification Factors

Common Motorway Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install w-section guardrail (around roadside hazards)		40% of all fatalities	N/A	High	These CRF only applies over isolated sections of guardrail. For continuous guardrail refer to following CRFs and CMFs. The factors where developed from primarily two-lane rural roads. If motorway factors do become available then these should be used.
		30% of all serious injury crashes	N/A	High	

Common Motorway Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
		10% of all minor injury crashes	N/A	High	
Install continuous combined roadside and median wire rope improvements (NEW)		65% of all injury crashes	0.35	Low	The factors where developed from primarily two-lane rural roads. If motorway factors do become available then these should be used.
		80%of all fatal and serious injury crashes	N/A	Low	
Install continuous flexible median barrier (NEW)		50% of all injury crashes	0.5	Low	The factors where developed from primarily two-lane rural roads. If motorway factors do become available then these should be used.
		60% of all fatal and serious injury crashes	N/A	Low	
		90% of fatal and serious head on crashes	N/A	Low	
Install continuous flexible roadside barrier (NEW)		15% of all injury crashes	0.85	Low	The factors where developed from primarily two-lane rural roads. If motorway factors do become available then these should be used.
		45% of run off road injury crashes	N/A	Low	
		65% of fatal and serious injury run off road crashes	N/A	Low	

Common Motorway Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install impact attenuators (NEW)	All	50% of all injury crashes	N/A	Medium	Research on CRFs and CMFs included assessments of attenuators located at tunnel portals, fixed objects, bridge pillars, and gore areas.
		70% of fatal crashes	N/A	High	
Street lighting (NEW)	New lighting – motorway and interchange to V3 level or better	31% of night-time injury crashes	0.91	High	Crash reduction factor based on night crashes only. CMFs based on 30% of crashes occurring at night. Where there is sufficient evidence (from the crash history) that a site has a higher or lower proportion than this then a site specific CMF should be developed. V3 lighting luminance level is >= 0.75 cd/m^2 (refer to AS/NZ standard 1158.1.1 for further details)
		47% of night-time fatal and serious injury crashes	N/A	Medium	

Table 36: Common intersection crash modification/reduction factors (urban and rural)

Common Intersection Crash Modification/Reduction Factors (Urban and Rural)					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Traffic Signals (urban).	Install traffic signals	Factors shall be determined using the priority, roundabout and signal prediction models outlined in 'Section 6.0 Intersections – Product of Flow Models'.			Research indicates that installation of traffic signals at three leg intersections are less beneficial than four legged intersections.
Linked / Coordinated signals (urban) (NEW).	Linking existing signals	15%	0.85	Medium	
Signal visibility (urban)	Replace a pedestal mount with a mast arm mount signal (NEW)	35% per treated approach	0.65 per approach	Low	This level of crash reduction will only occur at high volume intersections, especially where there are high proportions of trucks. Master arms are not normally used at lower volume traffic signals (as they will have a reduced effect).
	Increase lens size to twelve inches (NEW)	5% per treated approach	0.95 per approach	Low	Additional safety benefits may also be gained through the use of LEDs to improve signal visibility especially in areas prone to sunstrike.
	Provide additional signal head (NEW)	20% per treated approach	0.8 per approach	Medium	Only applicable where the number of signal heads is below the desirable
Install median (throat) island on side-road (rural)		35% per side-road approach	0.65 per approach	Medium	Crash reduction likely to be higher at cross-roads than T-junctions

Common Intersection Crash Modification/Reduction Factors (Urban and Rural)					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
Install right-turn lane	Install right-turn lane – signalised intersection (urban) (NEW)	30% per approach	0.7 per approach	Medium	
	Install right-turn lane(s) - unsignalised intersection (urban) (NEW)	35%	0.65	Medium	
	Install right-turn lane - rural unsignalised T-intersections (NEW)	40%	0.6	Low	
	Install right-turn lanes - rural unsignalised cross road intersections (NEW)	30%	0.7	Medium	
Install left-turn lane (NEW)	Urban intersections	20% per approach	0.8 per approach	Low	Additional crash reductions may be gained for cyclists if a cycle lane is installed between left and through lane.
	Rural intersections	0%	1.0	Low	The research and the benefits of left turn lanes on high speed intersections is inconclusive. While most research indicates that left turn slip lanes reduce crashes there are also studies that show that crashes may increase. A key issue with these lanes is that vehicles in the left turn lane may restrict visibility to through vehicles. This treatment should be applied with caution.
Staggered junctions – rural (converting cross	With minor road traffic < 15% of main road	35%	0.65	Low	Note that various stagger elements such as the stagger depth, alignment, and layout may significantly affect the potential benefits.

Common Intersection Crash Modification/Reduction Factors (Urban and Rural)					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
road junctions to two T – junctions) (NEW)	With minor road traffic 15-30% of main road	25%	0.75	Low	
	With minor road traffic > 30% of main road	35%	0.65	Low	
Intelligent active warning signs at rural intersections (e.g. RIAWS) (NEW)		35%	0.65	Medium	Crash reductions are likely to be higher for serious injury and fatal crashes due to reductions in operating speeds.
Static advance warning of rural intersections - where it is deemed necessary	All	7%	0.93	Low	
Install red light camera at signalised intersections (NEW)		5%	0.95	High	
Street lighting	New lighting – rural intersection	30%	0.9	Medium	Crash reduction factor based on night crashes only. CMFs based on 29% and 32% of crashes occurring at night in urban and rural intersections respectively. Where there is sufficient evidence (from the crash history) that an intersection has a higher or lower proportion than this then a site specific CMF should be developed.

Common Intersection Crash Modification/Reduction Factors (Urban and Rural)					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
	New lighting - urban intersection (NEW)	35%	0.9	Low	CRFs for pedestrian crashes are higher than presented here (see Table 36). Research indicates that lighting has very little effect on loss-of-control crashes.

Table 37: Common Urban Cyclist Crash Reduction/Modification Factors (apply only to crashes involving cyclists)

Common Cyclist Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
On-road cycle lanes	Standard	10%	0.9	Low	Less than 1.4 metres wide
	Wide (NEW)	20%	0.8	Low	Greater than 1.4 metres wide
Advanced cycle stop boxes	Intersections	35%	0.65	Low	Advanced stop boxes need to be to depths specific in cycling guidelines. Research indicates that the crash reduction is less when inadequate depth is provided.
Separated cycle paths alongside roads (NEW) – one way for cyclists	All crashes	0%	1.0	Low	The limited research available on cycle paths indicates that intersection and access crashes may increase as a result of these treatments, and may cancel the benefits that occur along mid-block sections. Where paths can be provided away from intersections and accesses crash benefits are likely. Where there are a lot of intersections and accesses without suitable mitigation of crash risk there may be an increase in cycle crashes. The main benefits of such facilities are a reduction in the perceived risk of cycling by the public. European experience indicates that two-way cycle paths have a much higher crash rate than one-way facilities. This is in part due to crossing motorists not expecting cyclists from both directions. The effect is exacerbated on one-way streets. As research becomes available on different cycle facilities these factors will be revisited.
Shared path (cycle and pedestrian) alongside roads (NEW) – one way for cyclists	All crashes	0%	1.0	Low	

Table 38: Common Urban Pedestrian Crash Reduction/Modification Factors (applies only to pedestrian crashes)

Common Pedestrian Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Improved lighting (NEW) at mid-blocks and intersections	Level V4	55%	N/A	Medium	Lighting luminance levels are as follows (refer to AS/NZ standard 1158.1.1 for further details) V1 >=1.5 cd/m^2 V2 >=1.0 cd/m^2 V3 >= 0.75 cd/m^2 V4 >= 0.50 cd/m^2 When upgrading lighting from one category to another (e.g. from V4 to V2) then pro rata the factors provided (e.g. upgrading from V4 to V2 gives a CRF of (1-0.55) x 0.80 = 36%
	Level V3	70%	N/A	Medium	
	Level V1 & 2	80%	N/A	Medium	
Add exclusive pedestrian phase at signals (Barnes dance) (NEW)	All	55%	0.45	Low	Should only be applied to intersections with high pedestrian volume in major commercial areas (like city centres)
Improve signal timing to reduce pedestrian delays (NEW)	All	35%	0.65	Low	Only applicable if major reductions in pedestrian delay can be gained.
Install pedestrian overpass	All	85%	0.15	Low	Where there are strong at grade desire-lines the benefit may be less.
Install raised platform	All	20%	0.8	Low	Treatment unsuitable for major roads. Normally introduced as part of area wide traffic calming schemes. *The 80% reduction specific in the previous version of EEM was an error.*

Common Pedestrian Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidence	Comment
Install pedestrian refuge	When kerbside parking	15%	0.85	Low	Higher reductions may be achieved on high volume roads. Crash reduction is likely to be lower when traffic lanes are 4m wide or greater (excluding cycle lanes). Based on lane width of around 3.5m.
	When no kerbside parking	45%	0.55	Low	
Install kerb extensions		35%	0.65	Low	Kerb extension must bring waiting pedestrians out beyond the line of parked vehicles, where inter-visibility between through traffic and pedestrians is adequate. Based on a traffic lanes of around 3.5m (excluding cycle lane where present). Crash reductions are likely to be reduced as traffic lanes width increase beyond 4m.
Install pedestrian refuge and kerb extensions		45%	0.55	Medium	Based on urban traffic lanes of around 3.5m (excluding marked cycle lanes). Crash reductions are likely to be reduced as traffic lanes width increase beyond 4m.
Install zebra crossing	Two-lane roads	0%	1.0	Low	Where speed limit is 50km/h or less. An increase in crash risk is likely on 2-lane roads with speed limits in excess of 50km/h
	Multi-lane roads (NEW)	90% increase in pedestrian crashes	1.90	Low	Research indicates that crash rates increase on multi-lane roads when the AADT is 12,000 or greater. Also, that the difference in pedestrian crash risk is not significant different in marked zebra crossings vs unmarked crossings on multi-lane roads with an AADT below 12,000.
Install mid-block traffic signals	All	45%	0.55	Low	Benefits are lower on multilane roads and where speed limit is above 50km/h.

Common Pedestrian Crash Reduction/Modification Factors					
Treatment	Sub type	Crash Reduction Factor	Crash Modification Factor	Confidenc e	Comment
Install fencing and barriers (NEW) to direct pedestrians	All	20%	0.8	Medium	Not applicable in all circumstances. Where pedestrian crossing desire-lines are strong pedestrians may jump the fence and crash reductions will be lower.
Traffic signals rest on red (NEW).	All	50%	0.5	Low	

9.0 Severity factors

The severity factors by intersection, midblock and by other site type are provided in Table 39 to Table 41 by transport mode involved. The total number of FSi for a subject site is calculated by aggregating the FSi equivalents for each mode type. For example the FSi for an urban roundabout (less than 80 km/h on all roads) with five motor vehicle injury crashes, and three cyclist injury crashes is calculated as follows:

5 (motor-vehicle crashes) * 0.13 = 0.65

3 (cyclists crashes) * 0.22 = 0.66

Total FSi = 1.31

For rural mid-blocks the terrain and alignment types will impact on the operating speed. For example, rural tortuous alignments are likely to have mean speeds of 50-70 km/h. The severity factor can be estimated by interpolating between mid-block factors of 50 km/h and 70 km/h.

Table 39: Urban Intersection (less than 80 km/h) FSi Severity Factors on all roads.

Urban Intersection (less than 80 km/h on all roads)	
Location and Mode	FSi Severity Factors
Signalised Cross roads (motor vehicles)	0.13
Signalised T-junctions (motor vehicles)	0.14
Roundabouts (motor vehicles)	0.13
Priority Cross roads (motor vehicles)	0.14
Priority T-junctions (motor vehicles)	0.15
Pedestrians	0.23
Cyclists	0.22
Motor-cyclists	0.24

Table 40: Rural Intersection (80 km/h plus on one intersecting road) FSi Severity Factors

Rural Intersection (80 km/h plus on one intersecting road)	
Location and Mode	FSi Severity Factors
Signalised Cross roads (motor vehicles)	0.27
Signalised T-junctions (motor vehicles)	0.20
Roundabouts (motor vehicles)	0.18
Priority Cross roads (motor vehicles)	0.35
Priority T-junctions (motor vehicles)	0.32
Pedestrians	0.48
Cyclists	0.32
Motorcyclists	0.47

Table 41: Mid-blocks and Special Sites FSi Severity Factors

Special Sites	
Location, Mode, and Operating Speed	FSi Severity Factors
Bridges (all speeds)	0.30
Mid-blocks 50km/h (motor vehicles)	0.15
Mid-blocks 50km/h (pedestrians)	0.26
Mid-blocks 70km/h (motor vehicles)	0.22
Mid-blocks 70km/h (pedestrians)	0.52
Mid-blocks 100km/h (motor vehicles)	0.26
Mid-blocks 100km/h (pedestrians)	0.64
Rail crossings (all speeds)	0.53

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Appendix 1

For use with crash data from CAS (Version 2.8 May 2010)

	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	SLOWER 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	OPPOSING RIGHT TURNS	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	ENTERING OR LEAVING FROM OPPOSITE SIDE	ENTERING OR LEAVING FROM SAME SIDE	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 (INCLUDING 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

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