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FINAL REPORT

R87: Development of Crash Reduction Factors (2018/19 – 2019/20)

ARRB Project No.: 014905

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SUMMARY

Crash reduction factors (CRFs) are an essential data component in the evaluation and prioritisation of road projects, used primarily to estimate economic savings in crashes for proposed road improvement works. This allows for various potential design options to be compared, works programs to be prioritised, benefit-cost ratios to be estimated.

Queensland Transport and Main Roads maintains its own body of knowledge in relation to CRFs. This knowledge, contained in a CRF matrix, has evolved over time and as such a review was required to ensure its continued alignment with current best practice and knowledge.

This project involved a comprehensive review of the CRFs. Information was drawn from both local and international sources, including current practice and literature, as well as through the collective knowledge of the Australian Road Research Board (ARRB) and Transport and Main Roads representatives in a series of intensive workshops.

Throughout this project multiple gaps in knowledge were identified for specific treatments and the context in which they are applied. This made the workshops pivotal, as often the expert experience and opinion of attendees was required to arrive at a value. This reasoning and judgement should also be applied by practitioners when using CRFs so that the site-specific context of the road safety project can be properly considered. In particular, CRFs identified were overwhelmingly general in nature, and for the most part did not take into account specific factors such as vehicle mode, traffic volume or speed enviroment. The impacts of these factors — and others — could form the basis of future project work.

The report details the outcomes of this work, including an updated CRF matrix, and describes how each of the updated values was arrived at.

CONTENTS

TABLES

GLOSSARY

Austroads reports – Collective term used throughout this document to refer to *Effectiveness of Road Safety Engineering Treatments* (Austroads 2012) and *Road Safety Engineering Risk Assessment Part 6: Crash Reduction Factors* (Austroads 2010).

AADT – Average annual daily traffic

Crash modification factor (CMF) – Relative metric to estimate the expected change in crash numbers associated with a particular treatment. Expressed as a decimal. A CMF is equivalent to 1 minus the CRF value. For instance, if a treatment has a CRF of 20%, the equivalent CMF would be 0.8.

Crash reduction factor (CRF) – Relative metric to estimate the expected reduction in crashes associated with a particular treatment. Expressed as a percentage. As it is a *reduction,* a negative CRF would refer to an increase in crashes.

CRF matrix – A description of TMR's current database of crash reduction factors, which currently exists in Microsoft Excel format.

FSI Crashes – Crashes that result in fatal or serious injury

1 INTRODUCTION

Crash reduction factors (CRFs) are essential data input for evaluating road projects. These are used primarily to estimate economic savings in crashes for proposed road improvement works. This allows for various potential design options to be compared, works programs to be prioritised, benefit-cost ratios to be estimated, etc.

Queensland Transport and Main Roads (TMR) maintains its own body of knowledge in relation to CRFs. The TMR CRF matrix has evolved over time and as such it was required to ensure its continued alignment with current best practice and knowledge.

The project objectives were to:

1. Undertake a review of existing CRFs and identify gaps in knowledge.
2. Based on a review of recent local and international research identify materials on treatment effectiveness for existing treatments and other treatments for consideration to add to the matrix.
3. Identify areas for which CRFs are not available or unreliable for further research.
4. Develop an updated CRFs matrix by vehicle type, traffic volume and different speed environment, if possible.
5. Production of Guidance Note / Users' manual for each CRF.
6. Production of User manual report outlining analysis process used (this report).

This project involved a comprehensive review of the CRFs within the matrix. Information was drawn from both local and international sources, including current practice and literature, as well as through the collective knowledge of the Australian Road Research Board (ARRB) and TMR representatives in a series of intensive workshops.

This report details the outputs of the review.

2 METHODOLOGY

In general, the project involved both jurisdictional review and expert consultation to identify current best practice values for the application of CRFs in Queensland.

The project involved three key stages:

1. Literature review, including
   a. current local best practice
   b. domestic and international literature
2. Workshops
3. Reporting.

Literature reviews and workshops were conducted by grouping treatments addressing the same primary crash types as specified in the existing TMR matrix. These crash types included:

- all
- head-on
- intersection
- run-off-road.
- other

Rear-end crashes were also reviewed, although they are not a primary crash type in the current TMR matrix.

2.1 LITERATURE REVIEW

2.1.1 CURRENT LOCAL BEST PRACTICE – JURISDICTIONAL OBSERVATIONS

CRFs are an important component for the costing of transport infrastructure projects – particularly those with an emphasis on safety. As such, several jurisdictions within Australia and New Zealand maintain their own databases of CRFs, although the manner and disaggregation of the data contained therein varies.

The following jurisdictions were reviewed as part of this project:

- Victoria – VicRoads (Department of Transport)
- New South Wales —Transport for New South Wales (TfNSW)
- South Australia – Department of Planning, Transport and Infrastructure (DPTI)
- Western Australia – Main Roads Western Australia (MRWA)
- New Zealand — New Zealand Transport Authority (NZTA).

Some general observations of the different approaches to recording CRFs were noted as follows:

- Not all of the treatments specified by TMR are used by each of the road agencies reviewed, and therefore , did not have comparable CRFs.
- Generally, the TfNSW CRFs showed the most similarity to the TMR CRFs, noting that TfNSW also disaggregated by crash type (road user movement codes) and speed zone (≤ 60km/h, 70–80 km/h, >80 km/h).
- TMR, TfNSW and DPTI disaggregated CRFs by speed and crash type, MRWA by crash type only and VicRoads and NZTA tended to provide all casualty reduction percentages.
- Two-thirds (60 out of 90) of NZTA CRFs were reported to have a low confidence level or none was provided.
- None of the reviewed treatments provided a breakdown of different road user types, traffic volumes or vehicle types. The exception to this was those that applied only to one road user type (i.e. pedestrian crossing reducing pedestrian crashes).

A comparison of the treatments included in each of the jurisdictional CRF tables is included at Appendix A.

2.1.2 DOMESTIC LITERATURE

It was noted that Austroads has completed substantial work in the area of CRFs in the recent past. In particular, *Road Safety Engineering Risk Assessment Part 6: Crash Reduction Factors* (Austroads 2010) outlines a number of crash reduction factors gathered from an extensive review of both domestic and international literature. Given the extensive nature of the study, the outcomes from the report have been adopted. This allows for this project to build upon the initial knowledge by focussing on new research not included in the 2010 study (i.e. literature published since 2010).

Some additional key sources of domestic literature include:

- *Effectiveness of Road Safety Engineering Treatments* (Austroads 2012)
- *Guide to Road Safety Part 8: Treatment of Crash Locations* (Austroads 2015a)
- *Road Safety Measures to Achieve Safe System Outcomes for Pedestrians* (Makwasha et al. 2017).

Further details on the sources for CRFs are provided in Appendix C. A full reference list is also provided . It is noted that throughout this document Austroads (2010) and Austroads (2012) are referred to collectively as the 'Austroads reports'.

2.1.3 INTERNATIONAL LITERATURE

The primary source of international research was the USA Crash Modification Factor (CMF) Clearinghouse, with information supplemented by the European Commission's SafetyCube project's decision-support system (SafetyCube DSS 2016).

The CMF Clearinghouse is an extensive repository of CMFs, designed to allow for the sharing of current knowledge and research, and managed by the Federal Highway Administration in the US A. Each of the CMFs uploaded to the Clearinghouse is star rated out of five for quality. The rating is based on a number of factors including study methodology, statistical analysis used, potential bias, and data source .

For ease of interpretation, a singular CRF was calculated from the literature gathered from the Clearinghouse by calculating a weighted average, with the star ratings used as the basis for the weighting, as per Equation 1. The resultant CRF is then rounded to the nearest 5%.

$$CRF_{WA} = \frac{RR_A * CRF_A + RR_B * CRF_B + \cdots}{RR_A + RR_B + \cdots} \quad (1)$$

where

CRF_{WA} = weighted average of crash reduction factor

RR_x = reliability rating of study x

CRF_x = crash reduction factor of study x

Direct comparisons between the domestic and international literature were difficult. As the Austroads work already calculated weighted scores from a number of studies, comparing this directly to the singular study values from the international work was not considered appropriate. Accordingly, this information has been presented separately in the literature review outputs and relative weighting between international and domestic literature performed on a case-by-case basis.

2.2 WORKSHOPS

Half-day workshops were conducted for treatments within each of the primary crash types to discuss the outcomes of the literature review and agree on recommended CRFs for inclusion in the revised matrix. Workshops were attended by staff from TMR and ARRB, comprised of engineers and researchers considered to have specialised expertise in risk assessment and crash causation and prevention in the context of Safe System principles. This process often required the application of professional expertise and experience to agree on a CRF value where research was either lacking or varied between sources. Consideration was also given as to what treatments were considered practical and/or desirable within the Queensland context, TMR's strategic goals and within the purview of its safety team (typically, infrastructure treatments that have a primary safety focus).

Prior to the workshops, summaries of the literature review outputs were circulated to all attendees for their review and consideration. Outputs from the workshops were also circulated to attendees to provide further comment where desired.

ARRB would like to acknowledge all those who attended the workshops and thank them for their input. A list of attendees is at Appendix D.

3 RESULTS

The primary output for this project is the updated TMR CRF matrix. This is provided at Appendix B.

Details of the literature underpinning the updates, and commentary from the workshops (as applicable) are provided in Appendix C. A summary of the revisions to the CRF matrix is presented in Table 3.1.

Table 3.1: Summary of revisions to CRF matrix

Treatment	Status	Appendix C number
All crashes		
General	Noted that 'all' crashes has been recategorised as 'other'	C.1
Bridges (widen or replace)	CRF removed from matrix, general information provided via cross-link	C.1.1
Alignment – change horizontal & vertical	Removed from matrix	C.1.2
Alignment – change vertical	Redefined as 'eliminate sub-optimal vertical geometry', CRFs revised	C.1.3
Duplicate road	Redefined as two treatments 'duplicate road – dual carriageway' and 'duplicate road – additional lanes' – CRFs updated	C.1.4
Route traffic calming scheme	CRFs updated	C.1.5
Install new seal on poor surface (wet surface crashes only)	Redefined to include all crash types, not just wet weather. CRFs updated	C.1.6
Install new signing – guide signs	Redefined as 'install new wayfinding signs', treatment life updated.	C.1.7
Install new signing – warning signs	Additional treatment 'Enhanced Signs' included to account for static warning signs being upgraded. CRFs revised , treatment life updated.	C.1.8
Install VAS speed roundel signs	Removed from matrix	C.1.9
Install VAS warning signs	CRFs revised.	C.1.10
Reduce speed limit to 80/90 km/h (reduced speed limit by 10 km/h)	Treatment redefined as 'reduce speed limit by 10 km/h', CRFs revised accordingly.	C.1.11
Install street lighting (night-time crashes only)	CRFs revised.	C.1.12
Head-on Crashes		
Audio-tactile Line Marking (ATLM) – Centreline (2.01)	CRFs updated	C.2.1
Centreline or Barrier Line Marking (2.02)	CRFs updated	C.2.2
Install wide centreline treatment with ATLM (2.03)	CRFs updated, treatment separated into two, with and without road widening	C.2.3
Install wide centreline treatment without ATLM (2.04)	No changes	C.2.4
Install painted median with wire rope safety barrier (2.05)	CRFs updated	C.2.5
Install RRPMs on centreline only (night-time crashes only) (2.06)	CRFs updated	C.2.6
Overtaking/Climbing Lanes (2.07)	CRFs updated	C.2.7
Install w-beam guardrail on median, dual carriageway (2.08)	CRFs updated	C.2.8
Install wire rope barrier on median from no existing barrier (2.09)	CRFs updated	C.2.9

Treatment	Status	Appendix C number
Install concrete barrier on median from no existing barrier (2.10)	CRFs updated	C.2.10
Replace w-beam median barrier with wire rope barrier (2.11)	Removed from matrix	C.2.11
Replace concrete median barrier with wire rope barrier (2.12)	Removed from matrix	C.2.12
Other treatments (not in current TMR matrix)	Several other treatments were proposed, but ultimately not incorporated	C.2.13
Intersection crashes		
Roundabout single lane (3.01)	CRFs updated	C.3.1
Roundabout two lane (3.02)	CRFs updated	C.3.2
Closure – one leg of x-intersection (3.03)	CRFs updated	C.3.3
Street closure – T-intersection (close stem of Tee) (3.04)	CRFs updated	C.3.4
Grade separation of intersection (3.05)	Removed from matrix	C.3.5
Median closure (extended median through intersection) (3.06)	CRFs updated	C.3.6
Stagger x intersection (x into staggered T, L/R configuration) (3.07)	CRFs updated, introduced R/L stagger configuration as additional treatment	C.3.7
Seagull island without acceleration lane, raised island (3.08)	Removed from matrix	C.3.8
Seagull island with acceleration lane, raised island (3.09)	Removed from matrix	C.3.9
Seagull island without acceleration lane, painted island (3.10)	Removed from matrix	C.3.10
Seagull island with acceleration lane, painted island (3.11)	Removed from matrix	C.3.11
Left-turn acceleration lane (3.12)	CRFs updated	C.3.12
Separate left-turn deceleration lane (painted or channelised) (3.13)	Treatment redefined as 'Improve sight lines for entering traffic by offsetting/channelising left-turn deceleration lane' – CRFs updated	C.3.13
Move limit forward using kerb extensions on priority road (3.14)	CRFs updated	C.3.14
Upgrade T-junction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right two lane (3.15)	CRFs updated	C.3.15
Upgrade T-junction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right-turn lane (only right-turn and rear-end crashes) (3.42)	Removed from matrix	C.3.16
Upgradeing T-junction from basic right turn (BAR) to CHR (3.16)q	Removed from matrix	C.3.17
Upgrading T-junction from basic right turn (BAR) to CHR (only right turn rear-end crashes) (3.43)	Removed from matrix	C.3.18
Upgrading T-junction from auxiliary right turn (AUR) to CHR (3.17)	CRFs updated	C.3.19
Upgrading T-junction from auxiliary right turn (AUR) to CHR (only right turn rear end crashes) (3.44)	Removed from matrix	C.3.20
Changing slip lane from low entry angle to high entry angle (3.18)	No changes	C.3.21

Treatment	Status	Appendix C number
Move limit lines forward using paint markings (3.19)	CRFs updated	C.3.22
Install transverse rumble strips on approaches (3.20)	CRFs updated	C.3.23
Install raised threshold at crossing point (3.21)	CRFs updated	C.3.24
Main Street Treatment (Kerb Extension/Median)	CRFs updated	C.3.25
Improve sight distance – remove impediments on main road (3.23)	Revised to relate specifically to non-vegetative obstructions, CRFs updated	C.3.26
Install new seal on unsealed approach to sealed road (3.24)	CRFs updated	C.3.27
Install new signing - stop sign at T-intersection (3.25)	No changes	C.3.28
Install new signing - stop sign at cross intersection (3.26)	CRFs updated	C.3.29
Install new signing - give way sign at T-intersection (3.27)	No changes	C.3.30
Install new signing – give-way sign at cross intersection (3.28)	No changes	C.3.31
Install new signing - prohibit right turn and/or U-turn - priority controlled (3.29)	This treatment has been combined with the following treatment (3.30) and CRFs revised	C.3.32
New signing - prohibit right turn and/or U-turn – signalised (3.30)	This treatment has been combined with the previous treatment (3.29) and CRFs revised	C.3.33
Install new signing - intersection warning (can including flashing lights with sign) (3.31)	This treatment was separated into static and dynamic warning signs and CRFs revised	C.3.34
Install additional priority signs on median islands (3.32)	Removed from matrix	C.3.35
Install lighting - intersection, night-time crashes only (3.33)	CRFs updated	C.3.36
Install new traffic signals: filter turns allowed (3.34)	Removed from matrix	C.3.37
Install new traffic signals: no filter turns allowed (3.35)	CRFs updated	C.3.38
Install fully control right turn with arrows (3.36)	CRFs maintained.	C.3.39
Introduce right turn phase while leaving filter (3.37)	Removed from matrix	C.3.40
Upgrade signal display (mast arm/additional lanterns) (3.38)	CRFs updated	C.3.41
S Lane Treatment – protected (3.39)	Removed from matrix	C.3.42
S lane treatment – painted (3.40)	Removed from matrix	C.3.43
Install extended length of raised median (3.41)	Treatment revised to 'install splitter islands on minor roads' and CRFs updated	C.3.44
Other Treatments	Several other treatments were proposed, but ultimately not incorporated	C.3.45
'Other' Crashes		
Install Painted Line to Separate Through & Parking Lane, reinforced with Kerb Ext.	Removed from matrix	C.4.1
Install Painted Line to Separate Through and Parking Lane	CRFs updated	C.4.2
Install Marked Pedestrian Crossing	CRFs updated, now recategorised as 'pedestrian' treatment	C.4.3

Treatment	Status	Appendix C number
Install Pedestrian - Kerb Extensions, Marked Pedestrian Crossing	Removed from matrix, now recategorised as 'pedestrian' treatment	C.4.4
Install Pedestrian - Kerb Extensions, No Crossing Marked	CRFs updated, now recategorised as 'pedestrian' treatment	C.4.5
Install Pedestrian - Mid-block Signals	CRFs updated, now recategorizsd as 'pedestrian' treatment	C.4.6
Install Pedestrian - Grade Separation	CRFs updated, now recategorised as 'pedestrian' treatment	C.4.7
Install Railway Level Crossing - Signs	No changes	C.4.8
Railway Level Crossing - Bridge/Underpass	No changes to CRFs, treatment life increased.	C.4.9
Install Railway Level Crossing - Barriers	Treatment redefined as 'install railway level crossing – boom gates', existing CRFs unchanged, however additional 'hit object' CRF added.	C.4.10
Install Railway Level Crossing - Flashing Lights	No changes	C.4.11
Recessed Bay for Stopping Vehicles	Treatment redefined as 'stopping bay', CRFs updated	C.4.12
Limit Access to Roadside Development	CRFs replaced with formula for calculation of CRFs.	C.4.13
High-friction Surfacing (calcined bauxite)	Now recategorised as 'rear-end' treatment, CRFs updated	C.6.6
Install New Seal on Unsealed Surface	CRFs updated, treatment life increased.	C.4.14
Provide Clearway/Parking Restrictions, Peak	CRFs updated	C.4.15
Provide Clearway/ Parking Restrictions, All Hours	CRFs updated	C.4.16
Install Lighting - Pedestrian Crossing Point (night time crashes only)	CRFs updated, , now recategorised as 'pedestrian' treatment	C.4.17
Capping ET2000 style guardrail terminals. (BICYCLE & MOTORCYCLE ONLY)	Treatment replaced with 'provide motorcycle barrier system'. CRFs updated accordingly. Recategorised as 'motorcycle' treatment.	C.4.18
Replacement of unsafe drain grates with AS 3996 compliant alternative. (BICYCLE & MOTORCYCLE ONLY)	No changes to CRFs, recategorized as 'motorcycle' treatment.	C.4.19
Replacement of access chamber covers in high friction demand locations (e.g. corners or deceleration zones) with a concrete infill class D cover. (BICYCLE & MOTORCYCLE ONLY)	No changes, recategorized as 'motorcycle' treatment.	C.4.20
Cutting back traffic islands that reduce shoulder width to less than 1 metre wide. (BICYCLE ONLY)	No changes to CRFs, recategorized as 'bicycle' treatment.	C.4.21
Establishing a bicycle lane where traffic volumes exceed 10,000 vpd in the direction of travel, posted speed 60km/h or greater and located on Principal Cycle Network or council trunk route (may involve posted speed review, parking restrictions).	Treatment revised as 'provide on-road bike lane, recategorized as 'bicycle' treatment.	C.4.22
Establishing a bicycle path or shared path where a bicycle lane is unsuitable (e.g. traffic sweeping across tight corner) or children could be expected to ride (within 2km of schools). (PEDESTRIAN & BICYCLE ONLY)	CRFs updated, treatment revised as 'provide off-road shared path/cycle path', recategorized as 'bicycle' treatment.	C.4.23
Installation of bicycle lanes at signalised intersections. (BICYCLE & MOTORCYCLE ONLY)	No changes to CRFs, recategorized as 'bicycle' treatment.	C.4.24

Treatment	Status	Appendix C number
Treatment of auxiliary left-turn lanes with TC1769 where applicable. (BICYCLE ONLY)	No changes to CRFs, treatment life increased, recategorized as ‘bicycle’ treatment.	C.4.25
Enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict particularly where there is evidence of motor vehicle sweeping through the bicycle lane. Possible treatments include ATLM, Green surface treatment, painted chevron buffer or splitter kerb. Refer Appendix C. (BICYCLE ONLY)	No changes to CRFs, treatment life increased, recategorized as ‘bicycle’ treatment.	C.4.26
Treatments to enhance bicycle safety at roundabouts (e.g. treatments to equalise motor vehicle and bicycle speed, increase driver alertness and enhance bicycle separation from traffic). (ROUNDABOUT ONLY)	No changes to CRFs, treatment life increased, recategorized as ‘bicycle’ treatment.	C.4.27
Installation of BAZ warning markings if appropriate, refer TRUM 1.39 (BICYCLE ONLY)	No changes to CRFs, recategorized as ‘bicycle’ treatment.	C.4.28
Install Refuge, No Crossing Marked (PEDESTRIAN & BICYCLE ONLY)	CRFs updated, recategorized as ‘pedestrian’ treatment.	C.4.29
Establishing an additional signalised crossings at intersections lacking crossings on all legs. (PEDESTRIAN & BICYCLE ONLY)	CRFs updated, recategorized as ‘pedestrian’ treatment.	C.4.30
Converting staged crossings to a single phase crossing where possible. (PEDESTRIAN & BICYCLE ONLY)	CRFs updated, treatment life increased, recategorized as ‘pedestrian’ treatment.	C.4.31
Fencing narrow width footpaths on bridges where path users might fall directly into a traffic lane. (PEDESTRIAN & BICYCLE ONLY)	No Changes to CRFs, recategorized as ‘pedestrian’ treatment.	C.4.32
Fencing median where crashes have occurred and crossing sight distance is not achieved. (PEDESTRIAN ONLY and ONLY AFTER ALL COMPLIANT CROSSING OPPORTUNITIES PROVIDED)	CRFs updated, recategorized as ‘pedestrian’ treatment.	C.4.33
Retrofit of pedestrian facilities where wheelchairs or mobility scooters have been known to become stuck on kerb ramps. (PEDESTRIAN ONLY)	CRFs removed, commentary on treatment provided, recategorized as ‘pedestrian’ treatment.	C.4.34
Rear-end		
Change fixed red-light speed camera to combined fixed digital red light/speed camera	New Treatment	C.6.8
High friction Surfacing (calcined bauxite)	Changed from ‘other’ treatment, CRFs updated	C.6.6
Additional treatments	Several other treatments were proposed, but ultimately decided to not be included. Further details can be found in Appendix C.6.	C.6
Run-off-road		
Install Audio Tactile Line Marking (ATLM) (Edge) with shoulder width ≥1m	CRFs updated	C.5.1
Install Edge-lines Marking Rural Road	CRFs updated	C.5.2
Install RRPM's on Centre and Edge Lines (night time crashes only)	CRFs updated	C.5.3
Install RRPM's on Edge Lines (night time crashes only)	Removed from matrix	C.5.4

Treatment	Status	Appendix C number
Change Horizontal Alignment	CRFs updated	C.5.5
Provide Acceptable Superelevation	Removed from matrix	C.5.6
Rest Area Provision	CRFs updated	C.5.7
Install shoulder from "no shoulder or unsealed" to ">1m sealed"	CRFs updated	C.5.8
Install shoulder from "no shoulder or unsealed" to "0.5-1m sealed"	CRFs updated	C.5.9
Sealed Shoulder 1.0 Metre from Through Lane	Removed from matrix	C.5.10
Sealed Shoulder 2.0 Metres from Through Lane	Removed from matrix	C.5.11
Install traversable headwall (Culvert impacts only)	CRFs updated	C.5.12
Install 5-6 m incremental traversable clearzones Widen clear zone (add 6m) Widen clear zone from 1m to 5m Widen clear zone (0-2) to (4-8) Widen clear zone (0-2) to (>8) Widen clear zone from 5-9.1m Install full-width traversable clear zone with 4:1 batter of flatter	These treatments were redefined to reduce overlap between treatment types and now consist of three treatments: • widen clear zone (0-2 m) to (2-4 m) • widen clear zone (0-2 m) to (4-8 m) • widen clear zone (0-2 m) to (> 8 m) CRFs were updated accordingly.	C.5.13
Flatten slope 1:3 to 1:4	This treatment was redefined as flatten slope 1:3 to 1:6. CRFs were revised accordingly	C.5.14
Flatten slope 1:4 to 1:6	CRFs updated	C.5.15
Treatment of Roadside Hazards - Removal Treatment of Roadside Hazards - Set Back	These treatments were removed from the matrix, noting they overlap with Widen Clear Zone treatments.	C.5.13
Treatment of Roadside Hazards - Frangible (slip base/impact absorbent)	CRFs updated.	C.5.16
Fencing of Stock	CRFs updated	C.5.17
Install w-beam guardrail on roadside from no existing barrier	CRFs updated	C.5.18
Install wire rope barrier on roadside from no existing barrier	CRFs updated	C.5.19
Install concrete barrier on roadside from no existing barrier	CRFs updated	C.5.20
Replace w-beam on roadside with wire rope barrier	Treatment removed from matrix.	C.5.21
Replace concrete barrier on roadside with wire rope barrier	Treatment removed from matrix.	C.5.22
Install guideposts with reflectors	CRFs updated	C.5.23
Install curve alignment markers (CAMs) on outside of curve	CRFs updated	C.5.24
Install curve alignment markers (CAMs) with existing advisory speed signs	Treatment removed from matrix	C.5.25
Grooving of Existing Pavement	CRFs updated	C.5.26

Additionally, guidance notes have been provided for each of the treatments to assist practitioners to understand the treatment and the relevance of the jurisdiction CRFs. These guidance notes are provided in the updated matrix and are based on the materials outlined in Appendix C.

3.1 ADDITIONAL EDITS

After the circulation of the draft version of the report, several changes to the matrix were undertaken by TMR to better reflect its procedural requirements. These changes are outlined in Table 3.2.

Table 3.2: Additional edits

Treatment	Scope of change
Eliminate sub-optimal vertical geometry	Values added for ‘other’ crash type (DCA 21)
Install Street Lighting (night-time crashes only)	Values added for ‘other’ crash type (DCA 21)
Install Central line or Barrier Line Marking	Values added for ‘other’ crash type (DCA 21)
Install wide centre line treatment with ATLM (road widening)	Values added for ‘other’ crash type (DCA 21)
Install wide centre line treatment with ATLM (paint only)	Values added for ‘other’ crash type (DCA 21)
Install painted median with Wire rope safety barrier	Values added for ‘other’ crash type (DCA 21)
Install w-beam guardrail on Median, Dual Carriageway	Values added for ‘other’ crash type (DCA 21)
Install wire rope barrier on median from no existing barrier	Values added for ‘other’ (DCA 21) and ‘out of control on curve’ crash types (DCA 20)
Install concrete barrier on median from no existing barrier	Values added for ‘other’ (DCA 21), ‘out of control on curve’ (DCA 20), and ‘out of control on straight’ (DCA 17)
Roundabout 1 lane	Additional values added for ‘off carriageway on straight’ (DCA 15), ‘off carriageway on straight, hit object’ (DCA 16), ‘out of control on straight’ (DCA 17), and ‘out of control on curve’ (DCA 20)
Roundabout 2 lane	Additional values added for ‘off carriageway on straight’ (DCA 15), ‘off carriageway on straight, hit object’ (DCA 16), and ‘out of control on straight’ crash types (DCA 17)
Upgrade T-junction from no existing treatment to Channelised right-turn treatment (CHR), pavement widening with a right-turn lane	Additional values added for ‘out of control on straight’ (DCA 17), ‘out of control on curve’ (DCA 20) and ‘other’ (DCA 21)
Upgrading T junction from Auxiliary Right Turn (AUR) to CHR	Additional values added for ‘out of control on straight’ (DCA 17), ‘out of control on curve’ (DCA 20) and ‘other’ (DCA 21)
Remove Slip Lane	Value added for service life
Signalise Slip Lane	Value added for service life
Improve Sight Distance: Remove Non-vegetation Impediments on Main Road	Additional values added for ‘Off carriageway on straight’ (DCA 15), ‘Off carriageway on straight, hit object’ (DCA 16), ‘Out of control, on straight’ (DCA 17) , ‘Other’ (DCA 21)
Install New Seal on Unsealed Approach to Sealed Road	Additional values added for ‘Off carriageway on straight, hit object’ (DCA 16), ‘Off carriageway on curve hit object’ (DCA 19), ‘Other’ (DCA 21)
Install Raised Threshold at Crossing Point	Additional values added for ‘Intersection, adjacent approaches’ (DCA 1), ‘Opposing Vehicles Turning’ (DCA 3), and ‘hit pedestrian’ (DCA 12) for high speed crashes
Install new signing - intersection warning (static)	Additional values added for ‘Off carriageway on straight’ (DCA 15), ‘Off carriageway on straight, hit object’ (DCA 16), ‘Out of control, on straight’ (DCA 17), ‘Off carriageway, on curve’ (DCA 18), ‘Off carriageway on curve hit object’ (DCA 19),’ ‘Out of control, on curve’ (DCA 20),’Other’ (DCA 21) crash types.
Install new signing - intersection warning signs (dynamic)	Additional values added for ‘Off carriageway on straight’ (DCA 15), ‘Off carriageway on straight, hit object’ (DCA 16), ‘Out of control, on straight’ (DCA 17), ‘Off carriageway, on curve’ (DCA 18), ‘Off carriageway on curve hit object’ (DCA 19),’ ‘Out of control, on curve’ (DCA 20),’Other’ (DCA 21)
Install Lighting – night-time crashes only	Additional values added for ‘Off carriageway on straight’ (DCA 15), ‘Off carriageway on straight, hit object’ (DCA 16), ‘Out of control, on straight’ (DCA 17), ‘Off carriageway, on curve’ (DCA 18), ‘Off carriageway on curve hit object’ (DCA 19), ‘Out of control, on curve’ (DCA 20) ,’Other’ (DCA 21)

Treatment	Scope of change
Install New traffic signals: filter turns not allowed	Additional values added for ‘Intersection, adjacent approaches’ (DCA 1) at high speed, values changed for ‘Opposing vehicles turning’ (DCA 3) and ‘U-Turn’ (DCA 7)
Install Fully control right turn with arrows	Values changed for ‘Opposing Vehicles Turning’ (DCA 3) and ‘U-turn’ (DCA 7)
Install splitter island on side roads	Values added for ‘Off carriageway on curve’ (DCA 18)
Install Painted Line to Separate Through and Parking Lane	Values added for ‘Out of control, on straight’ (DCA 17) , ‘Out of control, on curve’ (DCA 20) and ‘Other’ (DCA 21)
Install New Seal on Unsealed Surface	Values added for ‘Other’ (DCA 21)
Install RRPM”s on Centre and Edgelines (night time crashes only)	Values added for ‘Out of control on straight’ (DCA 17).
Rest Area Provision	This treatment has been divided into three separate treatments: • Provide New Rest Area (Benefits for 30 km either side of Rest Area on road) • Provide New Signage for Rest Area (Benefits for 30 km either side of Rest Area) • Upgrade Existing Rest Area (Benefits for 30 km either side of Rest Area on road) New CRFs have been provided for each of the treatments
‘Flatten slope 1:3 to 1:6’ and ‘Flatten slope 1:4 to 1:6’	Treatments redefined as: • ‘From lane edge, install a traversable slope (> 1:6) from 0 m existing to 1 m’ • ‘From lane edge, install a traversable slope from 1 m to 2 m (add if required)’ • ‘From lane edge, install a traversable slope from 2 m to 3 m (add if required)’ • Flatten slope to 1:6 or better (for at least the distance of the speed limit divided by 10) New CRFs have been provided
‘Widen clear zone (0-2) to (2-4)’, ‘Widen clear zone (0-2) to (4-8)’ and ‘Widen clear zone (0-2) to (>8)’	Treatments redefined as: • Install shoulder from existing 0.0m to 0.25m shoulder to 0.5m shoulder • Install shoulder from 0.5m shoulder to 1.0m shoulder (add if required) • Install shoulder from 1.0m shoulder to 1.5m shoulder (add if required) • Install shoulder from 1.5m shoulder to 2.0m shoulder (add if required) • Install shoulder from 2.0m shoulder to 2.5m shoulder (add if required) • Install shoulder from 2.5m shoulder to 3.0m shoulder (add if required) • Install shoulder from 3.0m shoulder to 3.5m shoulder (add if required) • Install shoulder from 3.5m shoulder to 4.0m shoulder (add if required) • From lane edge, install a traversable slope from 3m to 4m (add if required) • From lane edge, install a traversable slope from 4m to 5m (add if required) • From lane edge, install a traversable slope from 5m to 6m (add if required) • From lane edge, install a traversable slope from 6m to 7m (add if required) • From lane edge, install a traversable slope from 7m to 8m (add if required)

Treatment	Scope of change
	• From lane edge, install a traversable slope from 8m to 9m (add if required) • From lane edge, install a traversable slope from 9m to 10m (add if required) New CRFs have been provided.
"Fencing of stock"	New values added for 'head-on' (DCA 2), 'Off carriageway on straight' (DCA 15), 'Off carriageway on straight, hit object' (DCA 16), 'Out of control, on straight' (DCA 17), 'Off carriageway, on curve' (DCA 18), 'Off carriageway on curve hit object,' (DCA 19) 'Out of control, on curve' (DCA 20),'Other' crash types (DCA 21)
Install w-beam guardrail on roadside from no existing barrier	New values added for 'permanent obstruction' (DCA 13), 'out of control on straight' (DCA 17), 'out of control on curve (DCA 20)' and 'Other' (DCA 21). Values changed for 'off carriageway on curve, hit object' (DCA 19)
Install wire rope barrier on roadside from no existing barrier	New values added for 'permanent obstruction', 'out of control on straight', 'out of control on curve' (DCA 20) and 'Other' (DCA 21). Values changed for 'off carriageway on straight' (DCA 15), 'off carriageway on straight, hit object' (DCA 16) and 'off carriageway on curve hit object' (DCA 19)
Install concrete barrier on roadside from no existing barrier	New values added for 'permanent obstruction' (DCA 13), 'out of control on straight (DCA 17)', 'out of control on curve' (DCA 20) and 'Other' (DCA 21).

It is noted that these changes have been reflected in the matrix, but as they were undertaken after the workshops had concluded they have not been subject to the rigour of a workshop review and care should be taken with their use.

4 CONCLUDING REMARKS

Crash reduction factors remain a pivotal part of the planning and prioritisation of road safety infrastructure projects and it is likely that this will continue into the foreseeable future. They are not, however, absolute and unchangeable. Throughout this project it was identified that there were often gaps in knowledge around specific treatments and the context in which they are applied, requiring expert judgement of the workshop attendees to decide on a value. In particular, gaps in knowledge were identified around differentiating CRFs by vehicle type, traffic volume and/or speed environment for the majority of treatments, with the exception being road user specific treatments (e.g. pedestrian crossings, motorcycle rub rail) and speed environment for a select few. Developing this information could form part of a later project(s) if so desired noting it would require a signficiantly more detailed look at the performance characteristics of individual treatments.

Expert reasoning and engineering judgement needs to be applied whenever interpreting and using the revised matrix. All road safety infrastructure projects should be reviewed within the context in which they are proposed and consideration given to site specific as well as wider network conditions and the effects these may have on safety performance.

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APPENDIX A COMPARISON OF JURISDICTION CRF TABLES

Table A.1: Primary crash type – all crashes, jurisdictional availability

Primary crash type - all						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Bridges (widen or replace)	✓	✗	✓	✗	✗	✗
Alignment (change horizontal)	✓	✗	✗	✓	✗	✗
Alignment (change vertical)	✓	✓	✗	✓	✗	✗
Duplicate road	✓	✗	✓	✗	✗	✗
Route traffic calming scheme	✓	✗	✓	✓	✗	✓
Install new seal on poor surface (wet-surface crashes only)	✓	✓	✗	✓	✓	✗
Install new signing (guide signs)	✓	✓	✓	✗	✗	✗
Install new signing (warning signs)	✓	✓	✓	✓	✓	✓
Install vehicle activated signs (VAS) speed roundel signs	✓	✗	✓	✓	✗	✗
Install VAS warning signs	✓	✓	✓	✓	✗	✓
Reduce speed limit to 80/90 km/h (speed reduced by 10 km/h)	✓	✓	✓	✓	✓	✗
Install street lighting (night-time crashes only)	✓	✓	✓	✗	✓	✓

Table A.2: Primary crash type – head-on, jurisdictional availability

Primary crash type – head-on						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Install audio-tactile line marking (ATLM) centreline	✓	✓	✓	✓	✓	✓
Install centre line or barrier line marking	✓	✓	✓	✓	✗	✓
Install wide centre line treatment with ATLM	✓	✓	✓	✗	✗	✗
Install wide centre line treatment without ATLM	✓	✗	✗	✓	✓	✓
Install painted median with wire rope safety barrier	✓	✓	✓	✗	✓	✓
Install RRPMs on centre line only (night-time crashes only)	✓	✓	✓	✓	✗	✓
Overtaking/climbing lanes	✓	✓	✓	✗	✓	✗
Install w-beam guardrail on median, dual carriageway	✓	✓	✓	✓	✗	✓
Install wire rope barrier on median from no existing barrier	✓	✓	✓	✓	✗	✓
Install concrete barrier on median from no existing barrier	✓	✓	✗	✓	✗	✗
Replace w-beam on median with wire rope barrier	✓	✓	✗	✗	✗	✗
Replace concrete barrier on median with wire rope barrier	✓	✓	✗	✗	✗	✗

Table A.3: Primary crash type – intersection, jurisdictional availability

Primary crash type - intersection						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Roundabout one lane	✓	✓	✓	✓	✓	✗
Roundabout two lane	✓	✓	✗	✓	✓	✗

Primary crash type - intersection						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Street closure - one leg of x intersection	✓	✓	✓	✓	✓	✗
Street closure – T-intersection (close stem of T)	✓	✓	✗	✗	✓	✗
Grade separation of intersection	✓	✗	✓	✓	✓	✗
Median closure (extended median through intersection)	✓	✓	✗	✓	✓	✗
Stagger x intersection (x into staggered T, L/R configuration)	✓	✓	✓	✓	✓	✓
Seagull island without acceleration lane, raised island	✓	✗	✗	✗	✓	✗
Seagull island with acceleration lane, raised island	✓	✓	✗	✓	✗	✗
Seagull island without acceleration lane, painted island	✓	✗	✗	✗	✓	✗
Seagull island with acceleration lane, painted island	✓	✓	✗	✓	✗	✗
Left-turn acceleration lane	✓	✓	✗	✗	✓	✓
Separate left-turn deceleration lane (painted or channelised)	✓	✓	✓	✓	✓	
Move limit forward using kerb extensions on priority road	✓	✓	✗	✗	✗	✓
Upgrade T-junction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right-turn lane	✓	✓	✗	✓	✗	✓
Upgrade Tjunction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right-turn lane (only right-turn rear-end crashes)	✓	✗	✗	✗	✗	✗
Upgrading T junction from basic right turn (BAR) to CHR	✓	✓	✗	✗	✗	✗
Upgrading T junction from basic right turn (BAR) to CHR (only right turn rear end crashes)	✓	✗	✗	✗	✗	✗
Upgrading T junction from auxiliary right turn (AUR) to CHR	✓	✓	✗	✗	✗	✗
Upgrading T junction from auxiliary right turn (AUR) to CHR (only right turn rear end crashes)	✓	✗	✗	✗	✗	✗
Changing slip lane from low entry angle to high entry angle	✓	✗	✗	✗	✗	✗
Move limit lines forward using paint markings	✓	✓	✗	✗	✗	✗
Install transverse rumble strips on approaches	✓	✗	✓	✓	✗	✓
Install raised threshold at crossing point	✓	✓	✓	✗	✓	✓
Main street treatment (kerb extension/median)	✓	✗	✗	✗	✓	✗
Improve sight distance: remove impediments on main road	✓	✓	✗	✗	✓	✗
Install new seal on unsealed approach to sealed road	✓	✓	✓	✗	✗	✓
Install new signing - stop sign at t intersection	✓	✗	✓	✓	✗	✗
Install new signing - stop sign at x intersection	✓	✗	✓	✓	✗	✗
Install new signing - give way sign at t intersection	✓	✗	✓	✓	✗	✗
Install new signing - give way sign at x intersection	✓	✗	✓	✓	✗	✗
Install new signing - prohibit right turn and/or U-turn - priority controlled	✓	✓	✓	✓	✓	✗
New signing - prohibit right turn and/or U-turn - signalised	✓	✗	✓	✗	✗	✗

Primary crash type - intersection						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Install new signing - intersection warning (can including flashing lights with sign)	✓	✓	✓	×	×	×
Install additional priority signs on median islands	✓	×	×	×	×	×
Install lighting - intersection, night time crashes only	✓	✓	✓	×	✓	✓
Install new traffic signals: filter turns allowed	✓	✓	✓	✓	✓	×
Install new traffic signals: no filter turns allowed	✓	✓	✓	✓	✓	×
Install fully control right turn with arrows	✓	✓	✓	✓	✓	×
Introduce right turn phase while leaving filter	✓	✓	×	✓	×	×
Upgrade signal display (mast arm/additional lanterns)	✓	✓	✓	×	✓	×
S lane treatment - protected	✓	✓	×	×	×	×
S lane treatment - painted	✓	✓	×	×	×	×
Install extended length of raised median	✓	✓	✓	×	×	×

Table A.4: Primary crash type – run off road, jurisdictional availability

Primary crash type – run off road						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Install audio tactile line marking (ATLM) (Edge) with shoulder width ≥1m	✓	✓	✓	✓	✓	✓
Install edge-lines marking rural road	✓	✓	✓	✓	✓	✓
Install RRPM"s on centre and edge lines (night time crashes only)	✓	✓	✓	×	×	×
Install RRPM"s on edge lines (night time crashes only)	✓	×	✓	×	×	×
Change horizontal alignment	✓	✓	✓	✓	×	×
Provide acceptable superelevation	✓	✓	✓	✓	✓	✓
Rest area provision	✓	×	✓	×	×	×
Install shoulder from "no shoulder or unsealed" to ">1m sealed"	✓	✓	✓	✓	✓	×
Install shoulder from "no shoulder or unsealed" to "0.5-1m sealed"	✓	✓	×	✓	×	×
Sealed shoulder 1.0 metre from through lane	✓	✓	×	×	×	×
Sealed shoulder 2.0 metres from through lane	✓	✓	×	×	×	×
Install traversable headwall (culvert impacts only)	✓	✓	×	×	×	×
Install 5-6 m incremental traversable clear zones	✓	×	×	×	×	✓
Widen clear zone (add 6m)	✓	✓	✓	×	×	×
Widen clear zone from 1-5 m	✓	×	✓	×	×	×
Widen clear zone (0-2) to (4-8)	✓	×	✓	×	×	×
Widen clear zone (0-2) to (>8)	✓	×	✓	×	×	×
Widen clear zone from 5-9.1 m	✓	×	✓	×	×	×
Install full width traversable clear zone with 4:1 batter of flatter	✓	×	×	×	×	×
Flatten slope 1:3 to 1:4	✓	×	×	×	×	×

Primary crash type – run off road						
Treatment	**TMR**	**TfNSW**	**VicRoads**	**MRWA**	**DPTI**	**NZTA**
Flatten slope 1:4 to 1:6	✓	×	×	×	×	×
Treatment of roadside hazards - removal	✓	✓	×	✓	✓	×
Treatment of roadside hazards - set back	✓	×	×	✓	×	×
Treatment of roadside hazards - frangible (slip base/impact absorbent)	✓	×	✓	×	✓	×
Fencing of stock	✓	✓	×	×	×	×
Install w-beam guardrail on road side from no existing barrier	✓	✓	×	×	×	✓
Install wire rope barrier on road side from no existing barrier	✓	✓	×	×	×	✓
Install concrete barrier on road side from no existing barrier	✓	✓	×	×	×	×
Replace w beam on road side with wire rope barrier	✓	✓	×	×	×	×
Replace concrete barrier on road side with wire rope barrier	✓	✓	×	×	×	×
Install guideposts with reflectors	✓	✓	✓	×	×	×
Install curve alignment markers (CAMs) on outside of curve	✓	✓	✓	×	×	✓
Install curve alignment markers (CAMs) with existing advisory speed signs	✓	×	×	×	×	×
Grooving of existing pavement	✓	×	×	×	×	×

APPENDIX B UPDATED CRF MATRIX

Note: The updated CRF matrix was provided separately to this report in both PDF and excel formats. Please contact ARRB or TMR if access is required.

APPENDIX C CRF UPDATE MATERIALS

C.1 TREATMENT FOR ‘ALL’ CRASHES

During the workshop it was noted that the ‘all’ classification was potentially confusing as many treatments contained therein did not address all crashes. Therefore, it was decided to move these crash types into the ‘other’ classification.

C.1.1 BRIDGES (WIDEN OR REPLACE) (1.01)

Narrow bridges can create hazards between opposing streams of traffic by decreasing offsets between their travel paths or – in the case of single-lane bridges – place them in direct conflict.

Further, the need to protect bridge infrastructure and prevent vehicles overrunning the side, rigid containment barriers are often used, creating roadside hazards.

Widening or replacing existing bridges with wider bridges can help reduce these conflicts by creating greater separation between opposing traffic streams and between traffic and roadside hazards.

No existing CRFs exist for bridge widening within the Austroads reports.

A single international study was identified (Bigelow et al. (2010)) that relates the crash reduction factor to the original and new bridge widths. Equation A1 was developed from a 45 mph road (72 km/h) and the study was rated 3 stars for quality.

Equation A1: Crash reduction factor bridge width

$$CRF = 100 * (1 - e^{-0.116(Y-X)}) \qquad \textbf{A1}$$

where

CRF = crash reduction factor

X = original bridge width (m)

Y = new bridge width (m)

Source: Bigelow et al. (2010).

It is noted for this CRF that the value relates to the width of the bridge, minus the width of the road over the bridge. Accordingly, the road itself is not being widened as part of this treatment. The increased bridge width does however increase the offset to roadside hazards (i.e. bridge infrastructure, drop from side of bridge) and is expected to have a safety benefit.

The only other jurisdiction to provide a value for the widening or replacement of bridges was Victoria. A summary of the CRFs for bridge widening is shown in Table C.1.

Table C.1: Summary of CRFs for bridge widening

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
2	Head on	40		90					
9	Overtaking, same direction	40							
12	Hit pedestrian	40							
13	Permanent obstruction	40							
15	Off carriageway on straight	40							
16	Off carriageway on straight, hit object	40							
17	Out of control, on straight	40							
18	Off carriageway, on curve	40							
19	Off carriageway on curve, hit object	40							

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
20	Out of control, on curve	40							
	All casualty – bridge widening			30					
	All casualty – bridge replacement			45					
	Treatment life	20		25					

Note : L = low speed (<= 60 km/h), M = medium speed (70-80 km/h) and H = high speed (90 km/h+).

Discussions in the workshop noted that it was rare that a bridge would be widened purely on the basis of road safety and it was more commonly undertaken to increase capacity. Further, the combinations of baseline conditions and proposed design widths as well as the general lack of literature made it difficult to allocate a CRF to this treatment.

Accordingly, it was decided that the treatment would remain in the matrix, however specific CRFs would not be provided. Instead users are to contact the TMR Safer Roads section for discussion and the appropriate CRF to use, if required.

C.1.2 ALIGNMENT – CHANGE HORIZONTAL AND VERTICAL (1.02)

No specific literature was identified on the simultaneous changing of both vertical and horizontal alignment. It is noted that changes to horizontal alignment were covered in the run-off-road workshop and that changes in vertical alignment are outlined in the following section.

No other jurisdictions provided any new information on the combined CRF of changing both horizontal and vertical alignment. Nor was this information included in the Austroads reports. A summary of the CRFs is shown in Table C.2.

Table C.2: Summary of CRFs for changing alignment –both horizontal and vertical

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
2	Head on	50							
4	Rear end	40							
7	U-turn	15							
9	Overtaking, same direction	20							
11	Hit railway train	60							
12	Hit pedestrian	40							
13	Permanent obstruction	20							
14	Hit animal	20							
18	Off carriageway, on curve	25 (L), 35 (H)							
19	Off carriageway on curve hit object	25 (L), 35 (H)							
20	Out of control, on curve	25							
	Treatment life	20							

Note 1: L = low Speed (<= 60km/h) M = medium speed (70-80km/h) and H = high speed (90km/h+).

Given the lack of literature on this specific treatment, and the fact that horizontal and vertical alignment changes are already present in the matrix as individual treatments, it was decided this treatment would be removed from the matrix.

C.1.3 ELIMINATE SUB-OPTIMAL VERTICAL GEOMETRY (1.03)

An adverse vertical alignment can have a number of negative impacts on road safety including limiting driver sight lines – potentially disguising hazards such as intersections or sharp curves – and increasing stopping distances on downgrades.

No existing CRFs for changing vertical alignment were identified within the Austroads reports .

A single international study was identified by Choi et al. (2015). This study was rated 3 stars and outlines two equations for the calculation of the effect of changes in vertical grade on crashes, for changes in positive and negative grades. The equations are set out below.

Equation A2: Change negative vertical grade from G1 to G2

$$CRF = 100 * (1 - e^{(-0.0396*(G2-G1))}) \qquad \textbf{A2}$$

Equation A3: Change in positive vertical grade from G1 to G2

$$CRF = 100 * (1 - e^{(-0.0535*(G2-G1))}) \qquad \textbf{A3}$$

where

CRF = crash reduction factor

$G1$ = original vertical grade (%)

$G2$ = new vertical grade (%)

NSW and Victoria also provided CRFs for changing the vertical alignment. A summary of the CRFs is shown in Table C.3.

Table C.3: Summary of CRFs for changing vertical alignment

Crash type (DCA group)		TMR[1]	NSW[2]	VIC	WA	SA	NZTA	Austroads	Recent literature
2	Head on	15 (L), 5 (H)	15 (M), 5 (H)						
4	Rear end	15 (L), 5 (H)							
7	U-turn	10 (L), 5 (H)							
9	Overtaking, same direction	15	15 (M,H)						
11	Hit railway train	45							
12	Hit pedestrian	20							
13	Permanent obstruction	20							
14	Hit animal	20							
	All casualty			20					
	Treatment life	20							

1. *TMR definitions: L = Low Speed (< 80km/h) and H = High speed (>= 80km/h).*
2. *NSW definitions: L = Low Speed (<= 60km/h) M = Medium speed (70-80km/h) and H = High speed (>= 90km/h).*

It was decided in the workshop to redefine this treatment as 'eliminate sub-optimal vertical geometry' for clarity. Given the general consistency between jurisdictions and the identified research (noting Equation 2 produces a CRF of 15% for changing a -6% grade to a -2% grade) the outcome from the workshop was to maintain the existing CRFs and to include additional CRFs for DCA groups 15–20 which were previously excluded. The changes to the matrix are summarised in Table C.4 .

Table C.4: Summary of changes to CRFs for changing vertical alignment

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	15	5	15	15
4	301 - 303	Rear end	15	5	15	15
7	207, 304	U-turn	10	5	10	10
9	503, 505, 506	Overtaking, same direction	15	15	15	15
11	903	Hit railway train	45	45	45	45
12	001 - 009	Hit pedestrian	20	20	20	20
13	605	Permanent obstruction	20	20	20	20
14	609, 905	Hit animal	20	20	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight			15	15
16	703, 704, 904	Off carriageway on straight, hit object			15	15
17	705	Out of control, on straight			15	15
18	801, 802	Off carriageway, on curve			15	15
19	803, 804	Off carriageway on curve hit object			15	15
20	805 - 807	Out of control, on curve			15	15

C.1.4 DUPLICATE ROAD

Duplicating a road involves the construction of a second carriageway running parallel to the first. This allows for each of the carriageways – the new and the original – to carry traffic in a single direction separating opposing traffic streams and significantly increasing road capacity through the additional lanes. This type of road is often known as a divided road.

A single study was cited in the 2010 Austroads report for duplicating a carriageway. The stated CRF was 20.5% but it was noted as not being statistically significant and so is provided for information purposes only. VicRoads has a 20% reduction for duplication of urban arterial roads.

Two recent international studies were identified that look at the conversion of an undivided two-lane road to a divided four-lane road. A summary of the results is shown in Table C.5.

Table C.5: Duplicate road CRFs from international literature

Reference	All crashes	All casualty crashes	Fatal and serious injury	Minor injury
Ahmed et al.(2015)	66% (4 stars) – urban 29% (4 stars) – rural	63% (3 stars) – urban 45% (4 stars) – rural		
Elvik et al.(2017)	3% (4 stars)		75% (4 stars)	-5% (4 stars)
Weighted average (nearest 5)	35%	55%	75%	-5%

The summarised CRFs for duplicating a road are shown in Table C.6.

Table C.6: Duplicate road CRFs summary

Crash type (DCA Group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30							
2	Head on	100							

4	Rear end	30							
5	Lane change								
7	U-turn	30							
8	Entering roadway	50							
9	Overtaking, same direction	80 (L), 50 (H)							
10	Hit parked vehicle	15							
12	Hit pedestrian	50							
15	Off carriageway on straight	10							
16	Off carriageway on straight, hit object	10							
17	Out of control, on straight	10							
18	Off carriageway on curve	10							
19	Off carriageway on curve, hit object	10							
20	Out of control, on curve	10							
	All crashes								35
	FSI crashes								75
	Casualty crashes			20					55
	Minor injury								-5
	Treatment life	20		25					

Note : L = low speed (<= 80 km/h) and H = high speed (80 km/h+).

The results from recent literature were varied, particularly for 'all' crashes. However, the weighted averages from the weighted literature were overall not dissimilar from the existing CRFs within the table.

Given this, it was decided to maintain the existing values with adjustments made to CRFs as deemed appropriate and as discussed with workshop attendees. The changes are outlined in Table C.7 .

Table C.7: Summary of changes to duplicate road treatment (now known as duplicate road – dual carriageway)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches	30	30	30	30
2	201, 501	Head on	100	100	90	90
4	301 - 303	Rear end	30	30	30	30
7	207, 304	U-turn	30	30	-	-
8	401, 406 - 408	Entering roadway	50	50	-	-
9	503, 505, 506	Overtaking, same direction	80	50	80	80
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	15	15	15	15
12	001 - 009	Hit pedestrian	50	50	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight		10	30	30
16	703, 704, 904	Off carriageway on straight, hit object		10	30	30
17	705	Out of control, on straight		10	30	30
18	801, 802	Off carriageway, on curve		10	30	30
19	803, 804	Off carriageway on curve, hit object		10	30	30

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
20	805 - 807	Out of control, on curve		10	30	30

Further, it was decided to differentiate between a road duplication where a separate carriageway is constructed, and one where the width of the road is increased with a median to separate opposing traffic streams (although with significantly less separation than a full duplication). These treatments were defined as 'duplicate road – dual carriageway' (the CRFs for which are in the above table) and 'duplicate road – additional lanes' the CRFs for which are in Table C.8.

Table C.8: Duplicate road – additional lanes CRFs summary

Crash type (DCA gGroup)		Adopted values
1	Intersection, adjacent approaches	30
2	Head on	45
4	Rear end	30
5	Lane Change	-50
7	U-turn	
8	Entering roadway	
9	Overtaking, same direction	50
10	Hit parked vehicle	15
12	Hit pedestrian	30
15	Off carriageway on straight	30
16	Off carriageway on straight, hit object	30
17	Out of control, on straight	30
18	Off carriageway on curve	30
19	Off carriageway on curve, hit object	30
20	Out of control, on curve	30
	Treatment life	20

C.1.5 ROUTE TRAFFIC CALMING SCHEME (1.05)

A route-based traffic calming scheme is a different type of treatment to the majority of those within the matrix as it has a route rather than location focus. It is also by its nature a combination of individual treatments, all with the intended purpose of 'traffic calming', i.e. reducing vehicle operating speeds.

There are a number of treatments outlined in the CRF matrix that could be considered to have a traffic calming effect, including reducing speed limits (section C.1.11), roundabouts (section C.3.1), and transverse rumble strips (section C.3.23). Makwasha et al. (2017) indicated 65%, 70% and 35% CRFs for pedestrian casualty, pedestrian FSI and all casualty crashes respectively.

The Austroads report (2010), VicRoads and NZTA all indicate a CRF of 20% for route-based traffic calming (all casualty crashes). The summary CRFs are shown in Table C.9.

Table C.9: Route traffic calming CRFs summary

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	40							
2	Head on	40							
3	Opposing vehicles turning	40							
4	Rear end	40							
5	Lane change	40							

6	Parallel lane changing	40							
7	U-turn	40							
8	Entering roadway	25							
9	Overtaking, same direction	40							
10	Hit parked vehicle	40							
12	Hit pedestrian	30							
13	Permanent obstruction	40							
14	Hit animal	40							
15	Off carriageway on straight	25							
16	Off carriageway on straight, hit object	25							
17	Out of control, on straight	25							
18	Off carriageway on curve	40							
19	Off carriageway on curve, hit object	40							
20	Out of control, on curve	40							
21	Others								
	Casualty crashes			20			20	20	35
	Pedestrian crashes								65
	Pedestrian FSI								70
	Treatment life	15		20					

Traffic calming is primarily a speed management treatment. Accordingly, discussions in the workshop were that it was expected to have a similar effect across the majority of crash types. Based on the other jurisdictions and the Austroads literature, it was decided that the 40% CRF used for the majority of treatments in the existing matrix was too high. Accordingly a revised 30% value was adopted across the board. The changes are shown at Table C.10 .

Table C.10: Changes to route traffic calming scheme CRFs

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches	40		30	30
2	201, 501	Head on	40		30	30
3	202 - 206	Opposing vehicles turning	40		30	30
4	301 - 303	Rear end	40		30	30
5	305 - 307, 504	Lane change	40		30	30
6	308, 309	Parallel lanes turning	40		30	30
7	207, 304	U-turn	40		30	30
8	401, 406 - 408	Entering roadway	25		30	30
9	503, 505, 506	Overtaking, same direction	40		30	30
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	40		30	30
11	903	Hit railway train			30	30
12	001 - 009	Hit pedestrian	30		30	30
13	605	Permanent obstruction	40		30	30
14	609, 905	Hit animal	40		30	30
15	502, 701, 702, 706, 707	Off carriageway on straight	25		30	30

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
16	703, 704, 904	Off carriageway on straight, hit object	25		30	30
17	705	Out of control, on straight	25		30	30
18	801, 802	Off carriageway, on curve	40		30	30
19	803, 804	Off carriageway on curve hit object	40		30	30
20	805 - 807	Out of control, on curve	40		30	30
21		Other			30	30

C.1.6 INSTALL NEW SEAL ON POOR SURFACE (WET-SURFACE CRASHES ONLY)

Providing a new seal can improve surface friction, particularly in wet conditions.

Austroads (2016b) cited a 35% reduction in head-on crashes associated with this treatment, however it was noted that this was based on the RMS CRF.

One international study (Zeng et al. (2014)) was identified for the improvement of pavement condition on two-lane highways. This study noted an average 6.8% (increase) in all crashes and a 30.75% reduction in all casualty crashes.

TMR, NSW and SA all have CRFs relating to this treatment as shown in Table C.11.

Table C.11: Summary CRFs for installing new seal

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads
1	Intersection, adjacent approaches		35					
2	Head on	5	35					
3	Opposing vehicles turning		35					
4	Rear end	20	50			40		
11	Hit railway train	10						
12	Hit pedestrian		30					
13	Permanent obstruction		25					
14	Hit animal		25					
15	Off carriageway on straight	5	35					
16	Off carriageway on straight, hit object	5	35					
17	Out of control, on straight	5	40					
18	Off carriageway on curve	10	40					
19	Off carriageway on curve, hit object	10	40					
20	Out of control, on curve	10	40			30		
	All crashes							
	All casualty crashes							
	Treatment life	7						

It is noted that the Austroads value has been excluded from the table as it was based on the NSW CRF rather than an independent source.

The workshop decided to redefine this treatment type to include all crash types, rather than restrict it to be specifically wet-weather crashes. Given the consistently higher values for this treatment type across the available research and other jurisdictions, it was also decided to revise the CRFs upwards (see Table C.12).

Table C.12: Changes to CRFs for installing new seal

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches			5	5
2	201, 501	Head on	5	5	30	30
4	301 - 303	Rear end	20	20	30	30
11	903	Hit railway train	10	10	-	-
15	502, 701, 702, 706, 707	Off carriageway on straight	5	5	30	30
16	703, 704, 904	Off carriageway on straight, hit object	5	5	30	30
17	705	Out of control, on straight	5	5	30	30
18	801, 802	Off carriageway, on curve	10	10	30	30
19	803, 804	Off carriageway on curve hit object	10	10	30	30
20	805 - 807	Out of control, on curve	10	10	30	30
Treatment life			20		7	

C.1.7 INSTALL NEW SIGNING – GUIDE SIGNS

Guide signs provide early warning to drivers of upcoming streets etc. assisting with decision making and wayfinding and reducing erratic behaviour such as sudden lane changes.

Austroads (2012) cited a single study for the introduction of advance direction/warning signs. This study noted a 17% reduction in rear-end crashes and a 15% reduction in total crashes.

The international literature located one study, which was for the placement of advance street name signs. The study noted a minimal change in all and rear-end crashes (< 5%), however the reduction inside-swipe crashes was more significant at 10.3%.

Both TMR and NSW recorded CRFs for this crash type within their existing tables. The summary CRFs for guide signs are shown in Table C.13.

Table C.13: Summary CRFs for installing new guide signs

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
3	Opposing vehicles turning		15						
4	Rear end	10	20					15	5
5	Lane change	10	10						
6	Parallel lanes turning	10	15						10
9	Overtaking, same direction	10							
9	Overtaking, same direction, turning	10	20						
	All casualty			15				15	
	Treatment life	10		15					

It was decided in the workshop to redefine this treatment type as ‘install new wayfinding signs’. Additionally, CRFs for this treatment were revised to align with the Austroads work. The revised CRFs are outlined in Table C.14.

Table C.14: Changes to CRFs for installing new guide signs

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
3	202 - 206	Opposing vehicles turning			15	15
4	301 - 303	Rear end	10	10	15	15
5	305 - 307, 504	Lane change	10	10	15	15
6	308, 309	Parallel lanes turning	10	10	15	15
7	207, 304	U-turn			15	15
9	503, 505, 506	Overtaking, same direction	10	10	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight				5
16	703, 704, 904	Off carriageway on straight, hit object				5
17	705	Out of control, on straight				5
18	801, 802	Off carriageway, on curve				5
19	803, 804	Off carriageway on curve hit object				5
20	805 - 807	Out of control, on curve				5
Treatment life			10		15	

C.1.8 INSTALL NEW SIGNING – WARNING SIGNS

Intersection warning signs are covered in section C.3.34 and are not included in this section.

Austroads (2012) reported a 25% CRF for curve warning signs (all casualty crashes) as well as 17%, 30% and 30% for rear-end, run-off-road and head-on crashes respectively.

One international study – Choi et al. (2015) – was identified for the installation of chevron signs warning of – and guiding drivers through – horizontal curves. This study identified a CRF of 27.9% (rounded to 30%) for this type of treatment.

TMR, NSW and WA all detail crash reduction factors for this treatment type. The summary CRFs are shown in Table C.15.

Table C.15: Summary CRFs for installing curve warning signs

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
2	Head on	5	5		25			30	
4	Rear end	10 (L), 5 (H)	10		25			15	
13	Permanent obstruction	10 (L), 5 (H)	10						
15	Off carriageway on straight				25			30	
16	Off carriageway on straight, hit object				25			30	
17	Out of control, on straight				25			30	
18	Off carriageway, on curve		30		25			30	
19	Off carriageway on curve, hit object		30		25			30	
20	Out of control, on curve		30		25				
	Curve warning signs – all casualty							25	
	All crashes – chevrons on curves								30

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
	Treatment life	10							

Note: L = low speed (< 80 km/h) and H = high speed (80 km/h+).

It was noted in the workshop that a large amount of variability exists within the broad treatment type of warning signs; accordingly, this treatment was redefined as two separate treatments: 'install new signing – warning signs' and 'enhance existing signs', the former being standard road signs and the latter being making improvements to existing signs such as LEDs or other illumination.

It was noted that other jurisdictions consistently attributed higher CRFs with this treatment type. Accordingly, the existing CRFs were revised upwards (Table C.16). A standard 5% CRF was applied to crash types for sign enhancement Table C.17).

Table C.16: Changes to CRFs for installing new warning signs

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	5	5	20	20
4	301 - 303	Rear end	10	5	20	20
13	605	Permanent obstruction	10	5	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight			20	20
16	703, 704, 904	Off carriageway on straight, hit object			20	20
17	705	Out of control, on straight			20	20
18	801, 802	Off carriageway, on curve			20	20
19	803, 804	Off carriageway on curve hit object			20	20
20	805 - 807	Out of control, on curve			20	20
Treatment life			10		15	

Table C.17: CRFs for new treatment 'enhance signs'

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on			5	5
4	301 - 303	Rear end			5	5
13	605	Permanent obstruction			5	5
15	502, 701, 702, 706, 707	Off carriageway on straight			5	5
16	703, 704, 904	Off carriageway on straight, hit object			5	5
17	705	Out of control, on straight			5	5
18	801, 802	Off carriageway, on curve			5	5
19	803, 804	Off carriageway on curve hit object			5	5
20	805 - 807	Out of control, on curve			5	5
Treatment life			10		15	

C.1.9 INSTALL VAS SPEED ROUNDEL SIGNS

Vehicle activated signs (VAS) differentiate themselves from static signs by only providing information to a driver when certain conditions are met. In the case of speed signs, this is usually to enforce safe speeds or speed limits.

Austroads (2016a) provides a 35% CRF for the use of VAS generally, rather than specifically forspeed roundel signs.

One international study – Hallmark et al. (2015) – was identified for the use of dynamic speed feedback signs. The CRFs identified in this study were low at 7% and below. The summary CRFs for this treatment are shown in Table C.18.

Table C.18: Summary CRFs for installing VAS speed signs

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	35 (L), 30 (H)			80				
3	Opposing Vehicles Turning - Right through	30 (L)							
6	Entering roadway	30							
15	Off carriageway on straight	30							
16	Off carriageway on straight, hit object	30							
17	Out of control, on straight	30							
18	Off carriageway, on curve	30							
19	Off carriageway on curve, hit object	30							
20	Out of control, on curve	30							
	All crashes							35	5%
	All casualty – speed roundels (speed limit + slow down)			40					
	Treatment life	10							

Note 1: L = Low Speed (< 80km/h) and H = High speed (80km/h+).

The outcome from the workshop was to amalgamate this treatment type with the generic 'install VAS warning signs'. Accordingly, this treatment has been removed from the matrix.

C.1.10 INSTALL VAS WARNING SIGNS

Vehicle activated signs (VAS) differentiate themselves from static signs by only providing information to a driver when certain conditions are met (Figure C.1). The term is quite generic, and could relate to any number of possible use cases from the speed signs mentioned above to heavy vehicle height restrictions.

It is noted that Austroads (2016a) provides a general CRF of 35% for the use of VAS. Intersection conflict warning signs have been reviewed in Section No other sources were identified.

Figure C.1: VAS warning sign

Source: Austroads (2015b).

Queensland, New South Wales, Victoria and Western Australia all recorded CRFs for VAS as outlined in Table C.19.

Table C.19: Summary CRFs for installing VAS warning signs

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	35	15						
2	Head on		15						
3	Opposing vehicles turning	35 (L)	15						
8	Entering roadway	35							
12	Hit pedestrian		15						
15	Off carriageway on straight	35	25						
16	Off carriageway on straight, hit object	35	25			10			
17	Out of control, on straight	35	25			10			
18	Off carriageway, on curve	35	35						
19	Off carriageway on curve, hit object	35	35						
20	Out of control, on curve	35	35			10			
	All casualty							35	
	Rural intersections				70				
	All casualty – vVehicle activated speed limits				80				
	All casualty – speed roundels (speed limit + slow down)			40					
	All casualty – curve warning signs – winding road + too fast			55					

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
	All Casualty – Curve warning signs - Right sharp turn + Too fast			65					
	All Casualty – Curve warning signs - Right curve + slow down			40					
	All Casualty – Curve warning signs - Left curve + slow down			25					
	All Casualty – Intersection warning signs - cross intersection			50					
	All Casualty – Intersection warning signs - T-intersection			75					
	All Casualty – Variable Message Signs			20					
	Treatment life	10		15		10			

Note 1: L = Low Speed (<= 80km/h) and H = High speed (80km/h+).

Given the lack of consistency between the various sources and use cases, the CRFs were amended based on expert opinion of workshop attendees and a conservative approach was adopted, revising down CRFs slightly.

The changes to the matrix are outlined in Table C.20.

Table C.20: Changes to CRFs for installing VAS warning signs

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches	35	35	20	20
2	201, 501	Head on			20	20
3	202 - 206	Opposing vehicles turning	35		20	20
8	401, 406 - 408	Entering roadway	35	35	20	20
12	001 - 009	Hit pedestrian			20	20
15	502, 701, 702, 706, 707	Off carriageway on straight	35	35	20	20
16	703, 704, 904	Off carriageway on straight, hit object	35	35	20	20
17	705	Out of control, on straight	35	35	20	20
18	801, 802	Off carriageway, on curve	35	35	20	20
19	803, 804	Off carriageway on curve hit object	35	35	20	20
20	805 - 807	Out of control, on curve	35	35	20	20
Treatment life			10		15	

C.1.11 REDUCE SPEED LIMIT TO 80/90 KM/H(REDUCED SPEED LIMIT BY 10KM/H)

A strong correlation exists between crashes and vehicle speeds, both in terms of the likelihood of occurrence and the severity of outcomes. In the context of a reduction in the speed limit, it is important to note that the safety benefits will only be realised if the change in the limit translates to a change in operating speeds.

No literature was identified specifically on a reduction in the speed limit by 10 km/h to 80/90 km/h. Both NSW and SA recorded CRFs for this treatment type. It is noted that the NSW CRFs were based on a generic reduce speed limit by 10 km/h treatment and the SA CRFs assumed complementary treatments to help enforce the reduced limit.

Table C.21: Summary CRFs for reduce speed limit to 80/90 km/h (reducing speeds by 10 km/h)

Crash type (DCA group)		TMR[1]	NSW[2]	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
2	Head on	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)			15			
3	Opposing vehicles turning	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
4	Rear end	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)			15			
6	Parallel lanes turning	20 (L), 15 (H)	30 (L), 25 (M), 15 (L)						
7	U-turn	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
8	Entering roadway	20 (L), 15 (H)							
10	Hit parked vehicle	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
11	Hit railway train	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
12	Hit pedestrian	20	30 (L), 25 (M), 15 (H)			15			
13	Permanent obstruction	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
14	Hit animal	20 (L), 15 (H)	30 (L), 25 (M), 15 (H)						
15	Off carriageway on straight	10	30 (L), 25 (M), 15 (H)						
16	Off carriageway on straight, hit object	10	30 (L), 25 (M), 15 (H)						
17	Out of control, on straight	10	30 (L), 25 (M), 15 (H)						
18	Off carriageway, on curve	10	30 (L), 25 (M), 15 (H)						
19	Off carriageway on curve, hit object	10	30 (L), 25 (M), 15 (H)						
20	Out of control, on curve	10	30 (L), 25 (M), 15 (H)						
	FSIs			20					
	Treatment life	10		15					

1. *TMR definitions: L = Low Speed (< 80km/h) and H = High speed (>= 80km/h)*
2. *NSW definitions: L = Low Speed (<= 60km/h) M = Medium speed (70-80km/h) and H = High speed (>= 90km/h)*

It is noted that Victoria uses a more flexible approach for a reduction in speeds utilising the Nillson Power Model. This model allows for the prediction of changes in crash outcomes based on a change in mean speed. The model was refined by Elvik (2009) and updated again in 2019. It is noted that the 2019 update did not include exponents for serious injury crashes and as such is not considered appropriate for use in the TMR table.

The model, and the exponents based on the 2009 work by Elvik, are presented in Equation A4.

Equation A4: Power Model of the relationship between speed and road safety

$$\frac{Accidents\ before}{Accidents\ after} = \left(\frac{Speed\ after}{spped\ before}\right)^{Exponent} \qquad \text{A4}$$

Crash severity[1]	Exponent[2]
Fatal	4.1
Serious injury	2.6
Slight	1.1
All injury	1.6

1. *Injury exponents are also provided but were not considered relevant in this context.*
2. *Exponents provide are for all road types, urban/rural distinctions are also provided.*

Source: Elvik (2009).

During the workshop it was decided to maintain the matrix format rather than use a formula such as the Power Model. Further, the existing 90 km/h to 80 km/h reduction is to be removed in favour of a generic 10 km/h reduction. The CRFs were revised to be more closely aligned with the NSW CRFs and both low and high-speed CRFs were included, which reflects the fact that a 10 km/h reduction is a smaller relative change at high speeds than low speeds (i.e. 100 km/h to 90 km/h is a 10% reduction, 50 km/h to 40 km/h is a 20% reduction). The changes to the CRFs are outlined in Table C.22.

Table C.22: Summary CRFs for reducing speeds by 10 km/h

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches	20	15	30	20
2	201, 501	Head on	20	15	30	20
3	202 - 206	Opposing vehicles turning	20	15	30	20
4	301 - 303	Rear end	20	15	30	20
5	305 - 307, 504	Lane change			30	20
6	308, 309	Parallel lanes turning	20	15	30	20
7	207, 304	U-turn	20	15	30	20
8	401, 406 - 408	Entering roadway	20	15	30	20
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	20	15	30	20
11	903	Hit railway train	20	15	30	20
12	001 - 009	Hit pedestrian	20	20	30	20
13	605	Permanent obstruction	20	15	30	20
14	609, 905	Hit animal	20	15	30	20
15	502, 701, 702, 706, 707	Off carriageway on straight	10	10	30	20
16	703, 704, 904	Off carriageway on straight, hit object	10	10	30	20
17	705	Out of control, on straight	10	10	30	20

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
18	801, 802	Off carriageway, on curve	10	10	30	20
19	803, 804	Off carriageway on curve hit object	10	10	30	20
20	805 - 807	Out of control, on curve	10	10	30	20
21		Other			30	20
Treatment life			10		20	

C.1.12 INSTALL STREET LIGHTING (NIGHT–TIME CRASHES ONLY)

The installation of street lighting can help to identify potential hazards – such as rural intersections – as well as providing additional delineation of the roadway (Figure C.2).

Figure C.2: Street lighting

Source: Austroads (2015b).

As intersection lighting has been reviewed in the intersection workshop, the literature review discounted the CRFs associated with lighting at intersections. VicRoads specifies a 50% reduction for all night-time crashes. Austroads (2010) reported a 15% reduction for all casualty crashes. Two international sources (Abdel-Aty et al. (2014), Choi et al. (2015)) were also identified. Abdel-Aty et al. reported a 32% and 26% reduction (all crashes) for urban and all environments respectively. Choi et al. recorded a CRF of 7.8% for all crashes for an average CRF of 20% (both studies were rated 3 stars). Abdel-Aty et al. also reported on a number of other crash types as outlined in Table C.23.

Table C.23: Summary CRFs for installing street lighting (night-time crashes)

Crash type (DCA group)		TMR[1]	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20 (L), 25 (H)	20						
2	Head on	20 (L), 25 (H)	20						
3	Opposing vehicles turning	20 (L), 25 (H)	20						
4	Rear end	20 (L), 25 (H)	20						
5	Lane change	20 (L), 25 (H)	20						
6	Parallel lanes turning	20 (L), 25 (H)	20						

Crash type (DCA group)		TMR[1]	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
7	U-turn	20 (L), 25 (H)							
8	Entering roadway	10							
12	Hit pedestrian	20	40			30			
13	Permanent obstruction	25	20						
14	Hit animal	25	20						
15	Off carriageway on straight	25 (L), 30 (H)							
16	Off carriageway on straight, hit object	25 (L), 30 (H)							
18	Off carriageway, on curve	25 (L), 30 (H)							
19	Off carriageway on curve, hit object	25 (L), 30 (H)							
20	Out of control, on curve	25 (L), 30 (H)							
	All casualty crashes							15	
	All								20
	Rear end								35
	Single vehicle								35
	Angle								25
	Night-time crashes			50					
	Treatment life	10		2					

Note 1: L = Low Speed (<= 80km/h) and H = High speed (80km/h+)

It is noted that the recent literature did not specifically reference that the CRFs were for crashes occurring at night; while it is expected that this is where the majority of the benefit would be, some additional benefit may be provided by the enhanced delineation with the lamp columns acting as guide posts – even during the daytime.

Based on the general conformance with the identified literature, the outcome of the workshop was to make only slight adjustments to the existing values. The revised CRFs are outlined in Table C.24.

Table C.24: Summary CRFs for installing street lighting (night-time crashes)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
1	101 - 109	Intersection, adjacent approaches	20	25	25	20
2	201, 501	Head on	20	25	25	20
3	202 - 206	Opposing vehicles turning	20	25	25	20
4	301 - 303	Rear end	20	25	25	20
5	305 - 307, 504	Lane change	20	25	25	20
6	308, 309	Parallel lanes turning	20	25	25	20
7	207, 304	U-turn	20	25	25	20
8	401, 406 - 408	Entering roadway	10	10	25	20
12	001 - 009	Hit pedestrian	20	25	20	20
13	605	Permanent obstruction	25	25	20	25
14	609, 905	Hit animal	25	25	20	25

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
15	502, 701, 702, 706, 707	Off carriageway on straight	25	30	20	25
16	703, 704, 904	Off carriageway on straight, hit object	25	30	20	25
18	801, 802	Off carriageway, on curve	25	30	20	25
19	803, 804	Off carriageway on curve hit object	25	30	20	25
20	805 - 807	Out of control, on curve	25	30	20	25
	Treatment life		10		10	

C.2 TREATMENTS FOR HEAD-ON CRASHES

C.2.1 AUDIO-TACTILE LINE MARKINGS (ATLM) – CENTRELINE (2.01)

Audio-tactile line markings (ATLM) are raised patterns placed on or near road pavement markings – such as the centreline (Figure C.3). When wheels overrun the ATLM, a vibrating noise can be heard, alerting the driver that they are crossing the centreline. They are useful in addressing crashes related to driver inattention, distraction and fatigue. They may also improve visibility of the centreline during wet conditions and may discourage illegal crossing of the road centreline such as for overtaking (Austroads 2016b).

Figure C.3: Example of ATLM

Source: Austroads (2016b).

Table C.25 shows all identified recent studies into the effectiveness of ATLM. The relevant CRFs for head-on/cross centreline crashes presented have a weighted average of 35 (rounded).

A summary of the CRFs used by jurisdictions and the computed values from recent literature sources are provided in Table C.26. VicRoads specifies an 84% reduction in fatal head-on crashes. NZTA specifies a 30% reduction for head-on crashes and 15% reductions for all casualty crashes with a low-to-medium confidence level. Austroads (2016a) reported a 20–55% reduction (average of 35%) in head-on crashes and a 25–65% reduction (average of 40%) in FSI head-on crashes.

Table C.25: Install ATLM centreline CRFs from recent literature

Reference	Head-on	Cross centreline	FSI cross centreline	Run-off-road	All crashes	All injury crashes	All FSI crashes
Rys et al. (2012)		60% (4 stars)*		15% (4 stars)		34.1% (4 stars)	
Rys et al. (2012) **		90% (4 stars)**		55% (4 stars)**		60% (4 stars)**	
Kay et al. (2015)		27.3% (4 stars)	38.2% (3 stars)		15.8% (4 stars)		

Reference	Head-on	Cross centreline	FSI cross centreline	Run-off-road	All crashes	All injury crashes	All FSI crashes
Babiceanu and Fontaine (2018)		35.4% (3 stars)			7.5% (4 stars)	0.3% (4 stars)	
Datta et al. (2015)	50.8% (3 stars)				47.5% (3 stars)		46.6% (3 stars)
Sayed et al. (2010)		29.3% (4 stars)					18% (4 stars)
Guin et al. (2018)		42% (3 stars)					
Weighted average	35%		40%	15%	20%	15%	45%
Austroads (2010)					15%		
Austroads (2016b)	35%		40%		10%		20%

Values in red were excluded from calculations noting:
**These values were considered outliers.*
*** For football-shaped rumble strips.*

Table C.26: Summary of CRFs for installing ATLM centreline (centreline rumble strip) (% reduction)

Crash type (DCA group)	TMR	NSW	WA	SA	NZTA	Austroads (2016)	Recent literature
Head-on	20	25	15		30	35	35
Opposing vehicle turning	20						
Overtaking same direction	5	20	15	30			
Off carriageway on straight	10	20	15	30			15
Off carriageway on straight, hit object	10	20	15	30			15
Off carriageway on curve	10	20	15	30			15
Off carriageway on curve, hit object	10	20	15	30			15
Out of control	10	20	15	30			15
Out of control on curve	10	20	15	30			15
Treatment life (years)	5		3-5	5		5	

The CRFs for this treatment have been revised upwards to better align with the Austroads reports; it is noted that head-on crashes were reported as the same between the Austroads reports and the weighted average of the recent literature.

Table C.27: Summary of changes to CRFs for installing ATLM centreline (centreline rumble strip) (% reduction)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	20	20	25	25
3	202 - 206	Opposing vehicles turning	20	20	20	20
9	503, 505, 506	Overtaking, same direction	5	5	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight	10	10	20	20
16	703, 704, 904	Off carriageway on straight, hit object	10	10	20	20
17	705	Out of control, on straight	10	10	20	20
18	801, 802	Off carriageway, on curve	10	10	20	20
19	803, 804	Off carriageway on curve hit object	10	10	20	20
20	805 - 807	Out of control, on curve	10	10	20	20

C.2.2 CENTRELINE OR BARRIER LINE MARKING (2.02)

Centreline or barrier line markings are provided to visually guide drivers safely along the roadway by influencing their choice of position and speed. As shown in Figure C.4, the markings may comprise a (Austroads 2016b):

- double two-way line, consisting of two continuous lines side by side, indicating that crossing of the line is prohibited for both travel directions
- double one-way barrier line, featuring a continuous line beside a broken line, indicating that crossing of the line is permitted only for traffic travelling on the left of the broken line
- single barrier line, featuring a single continuous line, indicating that no overtaking is permitted, but crossing by traffic entering or leaving the roadway is permitted
- dividing line, featuring a single broken line, serving to separate traffic, but allowing crossing of the line for traffic travelling in either direction.

Figure C.4: Centreline or barrier line markings

(a) Double two-way line

(b) Double one-way barrier line

(c) Single barrier line

(d) Dividing line

Source: ARRB (2016b).

There is no recent literature that reported specifically on the effectiveness of installing centrelines for head-on crashes, however several were identified that provided CRFs for all FSI crashes. The studies provided CRFs for all crashes (Table C.28). Potts et al. (2011) reported a 38% reduction in all injury crashes on urban two-lane undivided roads and a 46% reduction in FSI crashes on multi-lane undivided rural roads. VicRoads has a reduction of 20% for all injury crashes. Austroads (2012) reported a 20% reduction for all crashes. Only TMR and NSW have CRFs for head-on crashes as shown in Table C.29.

Table C.28: CRFs from recent literature for installing centreline or barrier line marking

Reference	Head-on	FSI cross centreline	Run-off-road	All crashes	All injury crashes	All FSI crashes
Potts et al. (2011) – rural multi-lane undivided road	–	–	–	–	–	46% (3 stars)
Potts et al. (2011) – Urban multi-lane undivided road	–	–	–	–	–	8% (4 stars)
Potts et al. (2011) – Urban two-lane undivided road	–	–	–	–	38% (4 stars)	–
Weighted average	–	–	–	–	40%	25%

Reference	Head-on	FSI cross centreline	Run-off-road	All crashes	All injury crashes	All FSI crashes
Austroads (2010)	–	–	–	30%		
Austroads (2012)	–	–	–	20%		

Table C.29: Summary of CRFs for installing centreline or barrier line marking (% reduction)

Crash type (DCA group)	TMR	NSW	WA	SA	NZTA	Austroads (2016b)*	Recent literature
Head-on	10	15				15	
Overtaking same direction	35	20					
Overtaking, out of control	–	20					
Off carriageway on straight, to right	–	10					
Off carriageway on straight, hit object, to right	–	10					
Off carriageway on curve	–	5					
Off carriageway on curve, hit object	–	5					
Out of control on straight	–	5					
Out of control on curve	–	5					
Treatment life (years)	5					3	

** Austroads (2016b) quoted the NSW CRF.*

These CRFs were updated to align with the NSW CRFs which werealso quoted in Austroads (2016). It is noted that the chosen 15% is still less than the CRFs quoted in previous Austroads reports (2010, 2012) and is therefore considered a conservative value. The 'overtaking – same direction' CRF was scaled down based on expert opinion.

Table C.30: Summary of changes to CRFs for installing centreline or barrier line marking (% reduction)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	10	10	15	15
9	503, 505, 506	Overtaking, same direction	35	35	25	25
15	502, 701, 702, 706, 707	Off carriageway on straight			10	10
16	703, 704, 904	Off carriageway on straight, hit object			10	10
17	705	Out of control, on straight			5	5
18	801, 802	Off carriageway, on curve			5	5
19	803, 804	Off carriageway on curve hit object			5	5
20	805 - 807	Out of control, on curve			5	5

C.2.3 INSTALL WIDE CENTRELINE TREATMENT WITH ATLM (2.03)

Wide centrelines are a type of painted double line median treatment at least 1 m wide. An example is shown in Figure C.5. TMR technical guidelines recommend installing wide centrelines with ATLM. A NACOE study (R7) by Luy et al. (2018) re-examined the safety benefits of wide centreline treatments on the Bruce Highway based on analysis of four years of crash data before and after installation of the wide centrelines. The study found that the installation of wide centrelines reduced head-on FSI crashes by 30% and all head-on injury crashes by 33%, far lower than earlier studies. Notably, Austroads (2016b) specifies 50 to 80% reductions in head-on crashes; the 80% is based on the earlier study referenced in Luy et al. (2018), which has since been updated. There were no other updated CRFs in recent literature specifically for this combined treatment.

The TMR current matrix includes a 10% reduction for hit pedestrian crashes for this treatment. However, there are no sources in the literature or from other jurisdictionsto support the effectiveness of wide centreline treatments for hit pedestrian crashes. A summary of the CRFs is provided at Table C.31.

Figure C.5: Wide centreline treatment on the Bruce Highway with ATLM

Source: Luy et al. (2018)

Table C.31: Summary of CRFs for installing wide centreline treatment with ATLM (% reduction)

Crash type (DCA group)	TMR	NSW	VicRoads	NZTA	Austroads	Recent literature/ NACOE R7
Head-on	60	50	80	40	50–80%	35
Overtaking same direction	15	45				
Hit pedestrian	10					
Off carriageway on straight	40	50				
Off carriageway on straight, hit object	40	50				
Off carriageway on curve	10	45				
Off carriageway on curve, hit object	10	45				
Out of control, on straight	15	30				
Out of control, on curve	15	30				
Treatment life (years)	**5**		**15**		**5**	

Note: The 80% reduction specified by Austroads and VicRoads is based on an earlier study, which has been superseded by Luy et al. (2018).

It has been suggested that this treatment should be separated into two treatments with one including road widening and the other without road widening (i.e. painted only). CRFs were maintained for both, however painted only had a shorter treatment life (5 years vs 20 years) as shown in Table Table C.32 and Table C.33.

Table C.32: Changes to CRFs for installing wide centreline treatment with ATLM and road widening (% reduction)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	60	60	60	60
9	503, 505, 506	Overtaking, same direction	15	15	15	15
12	001 - 009	Hit pedestrian	10	10	10	10

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
15	502, 701, 702, 706, 707	Off carriageway on straight	40	40	45	45
16	703, 704, 904	Off carriageway on straight, hit object	40	40	45	45
17	705	Out of control, on straight	15	15	15	15
18	801, 802	Off carriageway, on curve	10	10	10	10
19	803, 804	Off carriageway on curve hit object	10	10	10	10
20	805 - 807	Out of control, on curve	15	15	15	15
Treatment life			20		20	

Table C.33: CRFs for installing wide centreline treatment with pain only (new treatment)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on			60	60
9	503, 505, 506	Overtaking, same direction			15	15
12	001 - 009	Hit pedestrian			10	10
15	502, 701, 702, 706, 707	Off carriageway on straight			45	45
16	703, 704, 904	Off carriageway on straight, hit object			45	45
17	705	Out of control, on straight			15	15
18	801, 802	Off carriageway, on curve			10	10
19	803, 804	Off carriageway on curve hit object			10	10
20	805 - 807	Out of control, on curve			15	15
Treatment life					5	

C.2.4 INSTALL WIDE CENTRELINE TREATMENT WITHOUT ATLM (2.04)

Figure C.6 provides an example of a wide centreline treatment without ATLM. It could be assumed that the crash reduction potential of a wide centreline without ATLM will be lower than that for a wide centreline with ATLM. No CRF could be sourced from recent literature specifically for this treatment. No jurisdictions other than the TMR matrix reported CRFs for this treatment (Table C.34).

Further research to determine a reliable CRF is recommended for this treatment. Currently, QLD has adequate road length with wide centrelines (with or without ATLM) that can be used to help develop statistically significant results in the future.

Figure C.6: Wide centreline treatment without ATLM

Source: ARRB.

Table C.34: Summary of CRFs for installing centreline treatment without ATLM (% reduction)

Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	Austroads	Recent literature
Head-on	30					
Overtaking same direction	15					
Hit pedestrian	10					
Off carriageway on straight	10					
Off carriageway on straight, hit object	10					
Off carriageway on curve						
Off carriageway on curve, hit object						
Out of control, on straight	15					
Out of control, on curve	15					
Treatment life (years)	**5**				**3**	

Given the lack of recent literature, it was decided to maintain the CRFs for this treatment at their existing values (Table C.35).

Table C.35: Summary of changes to CRFs for installing centreline treatment without ATLM (% reduction)

DCA group	Crash type (DCA code/description)		Old values		New values	
			Low speed	High speed	Low speed	High speed
2	201, 501	Head on	30	30	30	30
9	503, 505, 506	Overtaking, same direction	15	15	15	15
12	001 - 009	Hit pedestrian	10	10	10	10
16	703, 704, 904	Off carriageway on straight, hit object	10	10	10	10

C.2.5 INSTALL PAINTED MEDIAN WITH WIRE ROPE SAFETY BARRIER (2.05)

Figure C.7 shows a typical painted median with wire rope safety barrier treatment. The recent literature provided no new CRFs for this combined treatment. Austroads (2016b) specifies a 60 to 95% reduction in head-on crashes for the installation of wire rope safety barrier, and a 40 to 95% increase in run-off-road to the right crashes. The current TMR matrix includes a 20% reduction for crashes involving opposing vehicles turning.

Figure C.7: Example of a wire rope median barrier

Source: Google Earth (2019).

Table C.36: Summary of CRFs for installing painted median with wire rope safety barrier (% reduction)

Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
Head-on	95	95			90	60-95	
Opposing vehicle turning	20						
U-turn		95					
Overtaking same direction	50	95					
Off carriageway on straight	40	95					
Off carriageway on straight, hit object	40	95					
Off carriageway on curve	40	95					
Off carriageway on curve, hit object	40	95					
Out of control, on straight	40	95					
Out of control, on curve	40	95					
Treatment life (years)	**5**		**20**		**20**		

Given the general lack of recent literature for crashes other than the head-on type, CRFs for this treatment were based largely on expert opinion and modified to more closely align with NSW values (Table C.37).

Table C.37: Summary of changes to CRFs for installing painted median with wire rope safety barrier (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	95	95	95	95
3	202 - 206	Opposing vehicles turning	20	20	20	20
7	207, 304	U-turn			95	95
9	503, 505, 506	Overtaking, same direction	50	50	75	75
15	502, 701, 702, 706, 707	Off carriageway on straight	40	40	70	70
16	703, 704, 904	Off carriageway on straight, hit object	40	40	70	70

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
17	705	Out of control, on straight	25	25	70	70
18	801, 802	Off carriageway, on curve	40	40	70	70
19	803, 804	Off carriageway on curve hit object	40	40	70	70
20	805 - 807	Out of control, on curve	25	25	70	70

C.2.6 INSTALL RRPM"S ON CENTRELINE ONLY (NIGHT TIME CRASHES ONLY) (2.06)

Raised reflective pavement markers (RRPMs) are used to supplement pavement markings (centrelines, lane lines and edgelines) for increased effectiveness, especially in night and adverse weather (wet or foggy) conditions. An example of RRPMs during daylight hours is shown in Figure C.8. According to Austroads (2016b) the installation of RRPMs has the following crash reduction potential:

- 5% in all crashes
- 10% in all types of night-time crashes
- 20% for all types of crashes in wet, night-time conditions
- 15% in head-on crashes.

VicRoads and NZTA specify a 5% reduction for all casualty crashes. The only recent study by Sun and Das (2013) reported a 14% reduction in night-time crashes and a13% reduction for all crashes on roads carrying a maximum average annual daily traffic (AADT) of 60,000.

Table C.38 shows the CRFs from the various sources by DCA group.

Figure C.8: Example of RRPMs, day time

Source: ARRB.

Table C.38: Summary of CRFs for installing RRPMs – night-time crashes (% reduction)

Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	Austroads	Recent literature
Head-on	5	15			15	
Overtaking same direction	5	5				
Off carriageway on straight	5	15				
Off carriageway on straight, hit object	5	15				
Off carriageway on curve	10 (L), 15 (H)	15				
Off carriageway on curve, hit object	10 (L), 15 (H)	15				
Out of control, on straight		15				
Out of control, on curve		15				

Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	Austroads	Recent literature
All casualty			5	5	5	
Night-time					10	
Night-time, wet					20	
Treatment life (years)						

L = low speed < 80 km/h; H = high speed >= 80 km/h.

Given that both the NSW CRF matrix and Austroads reports pointed to a higher CRF value than currently observed in the TMR matrix, it was decided to factor up the CRF for head-on crashes (see

Table C.39: Summary of changes to CRFs for installing RRPM – night time crashes (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	5	5	10	10
9	503, 505, 506	Overtaking, same direction	5	5	5	5
15	502, 701, 702, 706, 707	Off carriageway on straight	5	5	10	10
16	703, 704, 904	Off carriageway on straight, hit object	5	5	10	10
17	705	Out of control, on straight			10	10
18	801, 802	Off carriageway, on curve	10	15	10	10
19	803, 804	Off carriageway on curve hit object	10	15	10	10
20	805 - 807	Out of control, on curve			10	10

C.2.7 OVERTAKING/CLIMBING LANES (2.07)

Overtaking lanes allow motorists to overtake slower-moving vehicles without moving into the opposing traffic lane. They provide increased road capacity, reduce driver frustration and inappropriate overtaking, and help to reduce the incidence of head-on collisions due to overtaking.

Both TMR and NSW specify 25% and 40% reductions in head-on and overtaking-type crashes respectively. VicRoads and NZTA specify 23% and 25% reductions respectively, for all injury crashes. South Australia indicates a 10% increase in lane-change crashes.

Austroads reports specify a 30% reduction in head-on crashes, but a 10% increase in lane-change crashes. Recent literature indicates a weighted average of a 35% reduction for head-on, side-swipe, rear-end and run-off-road crashes (Table C.40). A summary of CRFs for this treatment is provided in Table C.41.

Table C.40: Overtaking/climbing lane CRFs from recent literature

Reference	Head-on, run-off-road, side-swipe, other crashes	All injuries	All crashes
Bagdade et al. (2012)	47% (3 stars)	29% (3 stars)	33% (3 stars)
Schumaker et al. (2016)	25% (3 stars)	33% (3 stars	32% (3 stars)
Schumaker et al. (2016)	34% (3 stars)		
Park et al. (2012)		35% (4 stars)	
Weighted average	35%	35%	35%

Table C.41: Summary of CRFs for overtaking/climbing lanes (% reduction)

Crash type (DCA Group)	TMR	NSW	VicRoads	SA	NZTA	Austroads	Recent literature
Head-on	25	25		30	50	30	35
Overtaking same direction	40	40			30		35

Crash type (DCA Group)	TMR	NSW	VicRoads	SA	NZTA	Austroads	Recent literature
Off carriageway on straight	15(L), 30(H)	15					
Off carriageway on straight, hit object	15(L), 30(H)	15					
Off carriageway on curve	15(L), 30(H)	15					
Off carriageway on curve, hit object	15(L), 30(H)	15					
Out of control on curve	15(L), 30(H)						
Lane change crashes				-10		-10	
All injury crashes			23		25	16	
Treatment life (years)	**15**		**25**				

L = low speed < 80km/h; H = high speed >= 80km/h.

Based on the Austroads reports and recent literature, workshop attendees agreed that the current CRFs should be increased for head-on and reduced for overtaking-same direction crashes. Additional CRFs for off-carriageway type crashes were also introduced (Table C.42).

Table C.42: Summary of changes to CRFs for overtaking/climbing lanes (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	25	25	30	30
9	503, 505, 506	Overtaking, same direction	40	40	35	35
15	502, 701, 702, 706, 707	Off carriageway on straight	15	30	15	20
16	703, 704, 904	Off carriageway on straight, hit object	15	30	15	20
17	705	Out of control, on straight			15	20
18	801, 802	Off carriageway, on curve			15	20
19	803, 804	Off carriageway on curve hit object	15	30	15	20
20	805 - 807	Out of control, on curve			15	20

C.2.8 INSTALL W-BEAM GUARDRAIL ON MEDIAN, DUAL CARRIAGEWAY (2.08)

Median safety barriers are treatments used to prevent errant vehicles from entering the opposing lanes of traffic. They provide an effective way to reduce head-on crashes. An example of a w-beam median treatment is shown in Figure C.9.

W-beam barrier treatment can provide up to a 100% reduction in head-on crashes but lead to an increase in hit-object crashes. Alluri et al. (2012) reported that w-beam barriers prevent 95% of cross-median crashes, including almost 100% of crashes involving cars and 90% involving light trucks. The effectiveness for medium and heavy trucks was lower with reductions of 80% and 75% respectively.

Zou and Tarko (2018) reported that the average cost of a crash reduced by 50% when w-beam barrier is installed in medians less than 15 m wide. Their study confirmed that safety barriers lead to an increase in the total number of crashes, mainly due to collisions with the barriers and, in some cases, with other vehicles after being redirected back to traffic. However, overall the benefits of safety barriers exceed the negatives due to less severe outcomes and reductions in cross-median, rollover and hit-object crashes.

The effectiveness of installing w-beam barrier in the median reported in recent studies is shown in Table C.43. A summary of all CRFs reviewed isprovided in Table C.44. Only the TMR and NSW matrices guard rails including on the median.

Figure C.9: Example of w-beam median barrier

Source: ARRB.

Table C.43: W-beam guardrail CRFs from recent literature

Reference	Cross median	All injury crashes	All crashes
Graham et al. (2014)		-50% (3 stars)	-152% (3 stars)
Alluri et al. (2012)	95.4%		
Zou and Tarko (2018)			-80% (3 stars)
Weighted average	95%	-50%	-115%

Table C.44: Summary of CRFs for installing w-beam guardrail on median (% reduction)

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads (2016b)	Recent literature
Intersection – adjacent approaches	20							
Head-on	90	90					95	95
U-turn	100	95						
Entering roadway	50							
Overtaking same direction	100	95						
Off carriageway on straight	50	90						
Off carriageway on straight, hit object	65	90						
Off carriageway on curve	50	90						
Off carriageway on curve, hit object	65	90						
Out of control on straight		90						
Out of control on curve		90						
Treatment life (years)	**15**		**20**					

Table C.45: Summary of changes to CRFs for installing w-beam guardrail on median (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
2	201, 501	Head on	90	90	95	95
7	207, 304	U-turn	100	100	100	100

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
8	401, 406 - 408	Entering roadway	50	50	50	50
9	503, 505, 506	Overtaking, same direction	100	100	100	100
15	502, 701, 702, 706, 707	Off carriageway on straight	50	50	70	70
16	703, 704, 904	Off carriageway on straight, hit object	65	65	80	80
17	705	Out of control, on straight			90	90
18	801, 802	Off carriageway, on curve	50	50	70	70
19	803, 804	Off carriageway on curve hit object	65	65	80	80
20	805 - 807	Out of control, on curve			90	90

C.2.9 INSTALL WIRE ROPE BARRIER ON MEDIAN FROM NO EXISTING BARRIER (2.09)

An example of a wire rope barrier is shown in Figure C.10. Recent studies indicate that installing the barrier on a median is effective in reducing the severity of cross-median crashes, but increases total crashes (Alluri et al. 2012, Bryant et al. 2018, Olsen et al. 2011, Olson et al. 2013).

Alluri et al. (2012) reported that the installation of wire rope barriers resulted in a 38% increase in all median-related crashes, a 79% reduction in crossover crashes and a 27% reduction in FSI crashes.

The effectiveness of installing wire rope barrier in the median reported in recent studies is shown Table C.46. The results provided in thestudies are for the total cross-median crashes and do not consider only head-on crashes separately.

A summary of the CRFs by DCA group is shown in Table C.47. The TMR matrix provides CRFs for the effectiveness of wire rope barrier on adjacent intersection and entering roadway crashes. No other jurisdiction specifies CRFs for these crash types. VicRoads specifies a 14% reduction in FSI crashes on 100 km/h roads, a 26% reduction in FSI crashes on 110 km/h roads, and a 98% reduction in run-off-road FSI crashes to the right.

Figure C.10: Example of a median wire rope barrier

Source: ARRB.

Table C.46: Recent CRFs for installing wire rope barrier in the median

Reference/comment	Cross-median crashes	Cross-median FSI crashes	All crashes	All FSI crashes
Bryant et al. (2018)	50% (2 stars)		-15% (2 stars)	93% (2 stars)

Reference/comment	Cross-median crashes	Cross-median FSI crashes	All crashes	All FSI crashes
Olson et al. (2013)	65% (3 stars)	73.5% (2 stars)	-91% (3 stars)	
Olsen et al. (2011)	62% (3 stars)			44% (3 stars)
Alluri et al. (2012)	78.8% (3 stars)		-37.8% (3 stars)	
Gayah, VV & Donnell, ET (2014) / on curve	94% (4 stars)			
Gayah, VV & Donnell, ET (2014) / on tangent	100% (3 stars)			
Dissanayake and Galgamuwa (2017)			50% (2 stars)*	
Zou andTarko (2018)			-31% (3 stars)	
Russo et al. (2016) / 0.8-1.5 m median		53% (3 stars)		
Russo et al. (2016) / 1.5-2.9 m median		24% (3 stars)		
Weighted average	75%	45%	-45%	65%

** Considered an outlier, excluded from the weighted average; cross-median crashes include head-on crashes.*

Table C.47: Summary of CRFs for installing wire rope barrier in the median by DCA group (% reduction)

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Intersection, adjacent approaches	20							
Head-on	95	95				90	65-95%	75%
Overtaking same direction	100	95						
Entering traffic	50							
U-turn	100	95						
Off carriageway on straight	85	95	98					
Off carriageway on straight, hit object	90							
Off carriageway on curve	85		98					
Off carriageway on curve, hit object	90							
Out of control on straight		95						
Out of control on curve								
Treatment life (years)	**20**		**20**					

Based on the substantial literature supporting a significant reduction in head-on crashes from the installation of this treatment, a high CRF for this crash type was adopted (Table C.48). Little information was identified on the other crash types which were informed by expert opinion and by comparing these to the head-on crash type CRF.

Table C.48: Summary of changes to CRFs for installing wire rope barrier in the median by DCA group (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
2	201, 501	Head on	95	95	90	90
7	207, 304	U-turn	100	100	100	100
8	401, 406 - 408	Entering roadway	50	50	50	50
9	503, 505, 506	Overtaking, same direction	100	100	100	100
15	502, 701, 702, 706, 707	Off carriageway on straight	85	85	95	95

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
16	703, 704, 904	Off carriageway on straight, hit object	90	90	90	90
17	705	Out of control, on straight			95	95
18	801, 802	Off carriageway, on curve	85	85	90	90
19	803, 804	Off carriageway on curve hit object	90	90	90	90

C.2.10 INSTALL CONCRETE BARRIER ON MEDIAN FROM NO EXISTING BARRIER (2.10)

A typical concrete barrier is shown at Figure C.11.

Zou and Tarko (2018) reported that the average cost of a crash reduced by 50% when a concrete barrier is installed in medians less than 15 m wide.

Austroads (2016) reported the following CRFs for concrete median barriers:

- 100% reduction incross-median crashes
- 120% increase in single-vehicle run-off-road crashes
- a slight increase in all casualty crashes(the report does not distinguish between severity outcomes)
- 15% increase in injury crashes
- 90% and 10% reductions in fatal and injury crashes, respectively.

Figure C.11: Example of a median concrete barrier

Source: ARRB.

Recent literature on concrete barriers is shown in Table C.49. A summary of the litreature and recent jurisdictional practice is outliend at Table C.50.

Table C.49: Concrete median barrier CRFs from recent literature

Reference	Cross-median crashes	Single-vehicle crashes	All-injury crashes	All crashes	Fatal crashes
Zou andTarko (2018)				-168% (3 stars)	
Austroads (2016b)	100%	-120%	-15% + 10%		90%
Weighted average	100%	-120%	-5%	-170%	90%

Table C.50: Summary of CRFs for installing concrete median barrier by DCA group (% reduction)

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Intersection – adjacent approaches	20							
Head-on	95	75					100	
U-turn	100	95					100	
Entering roadway	50							
Overtaking same direction	100	95						
Off carriageway on straight	50	75						
Off carriageway on straight, hit object	65	75						
Off carriageway on curve	50	75						
Off carriageway on curve, hit object	65	75						
Out of control on straight		75						
Out of control on curve		75						
Treatment life (years)	**20**						**30**	

Given the substantial CRFs provided in the Austroads report, it was decided by workshop attendees to maintain the existing values for head-on crashes. The international literature was considered an outlier and not The other CRFs for this treatment type were also maintained, with slight revisions based on the expert opinion of attendees (Table C.51).

Table C.51: Summary of CRFs for installing concrete median barrier by DCA group (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
2	201, 501	Head on	95	95	95	95
7	207, 304	U-turn	100	100	100	100
8	401, 406 - 408	Entering roadway	50	50	50	50
9	503, 505, 506	Overtaking, same direction	100	100	100	100
15	502, 701, 702, 706, 707	Off carriageway on straight	50	50	65	65
16	703, 704, 904	Off carriageway on straight, hit object	65	65	70	70
18	801, 802	Off carriageway, on curve	50	50	65	65
19	803, 804	Off carriageway on curve hit object	65	65	70	70

C.2.11 REPLACE W-BEAM MEDIAN BARRIER WITH WIRE ROPE BARRIER (2.11)

No literature could be sourced regarding the effectiveness of replacing w-beam median barrier with a wire rope barrier. However, Zou and Tarko (2018) found wire rope barriers to be more effective than w-beam due to the smaller increase in total crashes caused by them and the less severe injury outcomes. Thus, installing wire rope barriers will result in less crashes with less severe outcomes than w-beam barriers, but some increase in cross-median crashes.

A summary of the current CRFs by DCA group is provided in Table C.52.

Table C.52: Summary of CRFs for replacing w-beam median barrier with wire rope barrier

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Head-on		50						
Off carriageway on straight		50						

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Off carriageway on straight, hit object	65	50						
Off carriageway on curve		50						
Off carriageway on curve, hit object	65	50						
Out of control on straight		50						
Out of control on curve		50						
Treatment life (years)	**20**						**30**	

As these barrier treatments have been considered separately it has been decided to remove this treatment from the matrix. The performance from changing from one type of barrier to another can be estimated by comparing the relative performance of the CRFs from both treatments.

C.2.12 REPLACE CONCRETE MEDIAN BARRIER WITH WIRE ROPE BARRIER (2.12)

No literature could be sourced regarding the effectiveness of replacing concrete median barrier with a wire rope barrier. However, Zou and Tarko (2018) found wire rope barriers to be more effective than concrete due to the smaller increase in total crashes caused by them and the less severe injury outcomes. Thus, installing wire rope barriers will result in less crashes with less severe outcomes than concrete barriers but with some increase in cross-median crashes.

A summary of the current TMR matrix is provided in Table C.53.

Table C.53: Summary of CRFs for replacing concrete median barrier with wire rope barrier

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Head-on		80						
Off carriageway on straight		80						
Off carriageway on straight, hit object	65	80						
Off carriageway on curve		80						
Off carriageway on curve, hit object	65	80						
Out of control on straight		80						
Out of control on curve		80						
Treatment life (years)	20						30	

As these barrier treatments have been considered separately it has been decided to remove this treatment from the matrix. Performance from changing from one type of barrier to another can be estimated by comparing the relative performance of the CRFs from both treatments.

C.2.13 OTHER TREATMENTS (NOT IN CURRENT TMR MATRIX)

The section details other head-on crash treatments not currently included in the TMR matrix that were suggested for inclusion.

While ultimately it was decided that none of these treatments was to be included in the matrix, the information on each is provided for reference.

Audio-tactile line marking (ATLM) – centreline and shoulder

An example of combined centreline and shoulder ATLM is shown in Figure C.12. Table C.54 shows the CRFs for installing both shoulder and centreline rumble strips. It ranges from 32% to 71% for head-on/cross-centreline crashes and 26% to 62% for run-off-road crashes. Galgamuwa andDissanayake (2017) and Sayed et al. (2010) reported reductions of 14% and 21% respectively for lane-departure crashes (i.e. head-on, side-swipe and run-off-road crashes).

Figure C.12: Example of centreline and shoulder ATLM

Source: ARRB.

Table C.54: Effectiveness (CRFs) of installing combined ATLM centreline and shoulder

Reference	Head-on	Head-on FSI	Run-off-road	Lane departures[1]	All crashes
Olson et al. (2013)	71% (3 stars)	57.5% (2 stars)	61.6% (3 stars)	66% (3 stars)	
Kubas et al. (2013)			29% (2 stars)		2% (2 stars) [2]
Persaud et al. (2015)	36.8% (5 stars)		25.8% (5 stars)		20.0% (5 stars)
Kay et al. (2015)	32.8% (4 stars)				17.2% (4 stars)
Galgamuwa andDissanayake (2017)				14% (3 stars)	
Sayed et al. (2010)				21.4% (4 stars)	
Austroads (2016b)	35-65%	35%		20-65%	20%
Weighted average CRF	45%	45%	35%	35%	15%

1. *Lane departures include head-on crashes.*
2. *Outlier, excluded from calculations.*

Enhanced pavement markings

Enhanced pavement markings, also termed long-life road markers, improve the reflectivity of road markers and hence their night-time visibility. This treatment reduces the risk of crashes during times of darkness (Austroads 2016b).

The treatments include the following (Taylor et. al. 2017):

- Profiled thermoplastic centreline stripes – moderate-cost treatment that improves the visibility of a centreline system at night, particularly in wet conditions. An additional advantage is that it seems to have a mild audio-tactile response, alerting drivers straying from lanes. This treatment suits several road sections: (a) with long unbroken centrelines where traffic volumes and crash history do not justify raised profiled centrelines or other more expensive treatments, (b) where there is a high number of wet-weather crashes, or (c) where pavement maintenance is not scheduled for at least three years.
- Cold applied plastic materials – a two-part liquid mix of resin-based material and hardener. To improve reflectivity, glass beads are pre-mixed into the product, and additional beads are dropped on during application. Due to its high wear resistance this product is typically used at intersections.
- Road-marking tape – may be flat or profiled. Retroreflective glass beads are incorporated into the material during its production. Its cost is high compared to other linemarking options, so use is generally limited to areas where a high level of performance is required under severe conditions, or to repair or

replace sections of deteriorated linemarking. The reflectivity is about four-to-six times that of water-borne traffic paints; however, the reflectivity quickly diminishes.

Austroads (2016b) specified a 10–15% reduction in night-time midblock crashes due to enhanced pavement markers, but no specific head-on crash reduction data was available. The effectiveness of enhanced pavement markers is shown in Table C.55.

Table C.55: Effectiveness of enhanced pavement markers

Reference	Material	Night-time crashes	Night-time wet crashes
Austroads (2016b)	Profile thermoplastic	10–15%	-
	Road-marking tape	10–15%	-

Painted median

Painted medians are a low-cost option used to address head-on crashes by improving the separation of vehicles and discouraging overtaking. Painted medians are used where there is limited road width for the installation of raised medians. Narrowing the road using painted medians may also help to reduce travel speeds and encourage drivers to travel at a more suitable speed for the road environment (Austroads 2016b).

Painted medians can be used in both urban and rural areas. In urban areas, they provide some protection to pedestrians crossing the road; they may be coupled with pedestrian crossing facilities, such as refuge islands, to provide added security. An example of a painted median is shown in Figure C.13.

For maximum benefits, the width of the painted medium should be at least 1.0 mwide (Austroads 2016b). The identified recent literature is outlined at Table C.56. A summary of CRFs by DCA group is shown in Table C.57.

Figure C.13: Examples of a painted median

Source: ARRB.

Table C.56: Effectiveness of painted median

Reference	Head-on crashes	Injury crashes	All-injury crashes
iRAP (2010)	-	-	10–25%
Austroads (2012)	-	15%	-
Austroads (2016b)	40%		15–20%
NSW RMS	40%		
VicRoads	50%	20%	
NZTA		15%	

Table C.57: Effectiveness of painted median by DCA group

Crash type (DCA group)	TMR	NSW	VicRoads	WA	SA	NZTA	Austroads	Recent literature
Head-on		40	50					
Overtaking same direction		55						
Hit pedestrian		25	50					
Off carriageway on straight		20						
Off carriageway on straight, hit object		20						
Off carriageway on curve		20						
Off carriageway on curve, hit object		20						

Raised medians

Raised medians are often used in urban and semi-urban roads to provide a physical deterrent in terms of preventing cross-median manoeuvres. Raised medians can also accommodate sign posts, lighting and traffic hardware and may be landscaped to improve aesthetics and to reduce headlight glare (Austroads 2016b). An example of a raised median is shown in Figure C.14.

Figure C.14: Example of a raised median

Source: ARRB.

Austroads (2016b) suggests casualty crash reduction factors of 45% and 55% in urban and rural areas, respectively.

Table C.58: Effectiveness of raised median from literature

Reference	Head-on	All crashes	All injury crashes	All FSIs	Angle	Comment
Austroads (2016b)	60%		40-55%	45%		Install raised median
Schultz et al. (2011)		39%		44%		Install raised median
Schultz et al. (2008)		71%			55%	Install raised median
Yanmaz-Tuzel and Ozbay (2010)		14%				
Abdel-Aty et al. (2014)	73%	47%	33%			Convert median turning lane to raised median

Median turning lane

The main function of this treatment is to allow turning into driveways and entrances. Studies have shown that median turning bays can be used to reduce head-on crashes by creating a buffer between the opposing streams of traffic (Austroads 2016b).

An example of a median turning lane is shown in Figure C.15. Two-way turning lanes are typically used in busy urban areas with closely-spaced access points. This type of lane also provides a space for drivers of turning vehicles who must wait for an adequate gap in the oncoming traffic and therefore can be implemented in urban fringes for improved safety. In areas where there is pedestrian activity, these lanes may provide some protection to pedestrians crossing the road; they can be coupled with pedestrian treatments such as pedestrian refuge islands to provide added security (iRAP 2010).

Figure C.15: Example of a median turning lane

Source: ARRB.

Median turning bays or a road diet treatment can be installed on four-lane undivided roads by modifying the layout to a three-lane roadway with the middle lanes used as a median turning bay.

Austroads (2016b) reported that, based on an earlier study of expert opinion alone, it was suggested that this treatment should reduce head-on crashes by 35%, and all crash types by 30%. iRAP (2010) suggests a 10–25% crash reduction for median turning bays (see Table C.59).

Table C.59: Effectiveness of median turning lane

Reference	Head-on crashes	All crashes
iRAP (2010)		10-25%
Austroads (2016b)	35%	30%

Improved curve delineation – chevron alignment markers

Chevron alignment markers (CAMS) are used to indicate the presence and severity of curves thereby enabling motorists to select the appropriate travel speed fora curve. An example of a curve with well delineated CAMs is shown in Figure C.16.

Figure C.16: Example of a curve delineated with CAMs

Source: ARRB.

CRFs sourced from recent literature are shown in Table C.60.

Table C.60: Effectiveness of CAMs

Reference	Head-on	All injury	Daytime	Night-time
Austroads (2010)		30%		
Austroads (2012)		25%		
Austroads (2016b)	75%	50%	40%	55%
NSW RMS (2015)	20%			

Two plus one (2+1) road with wire rope

On two-way roads, a 2+1 lane treatment is implemented to prevent head-on and median crossover crashes. The treatment consists of a three-lane cross-section. The outside lanes serve as a general traffic lane for one direction each. The centre lane serves as an overtaking lane for each direction of travel, alternating every 1–2.5 km, with a transition zone of up to 300 min length. The opposing traffic is usually separated by a wire rope barrier (Figure C.17).

This treatment is recommended for roads with traffic flow rates of up to 1200 veh/h in one direction of travel (Austroads 2016b).

Figure C.17: Example of a two plus one road with a wire rope barrier

Source: ARRB.

Austroads (2016b) reported the following crash reductions for two plus one roads:

- 80% in fatal crashes

- 40–50% in motorcyclist FSI crashes
- 110 km/h roads: 75% reduction in the fatal crash rate
- 90 km/h roads: 80% reduction in the fatal crash rate
- 55% in FSI crashes (all crash types).

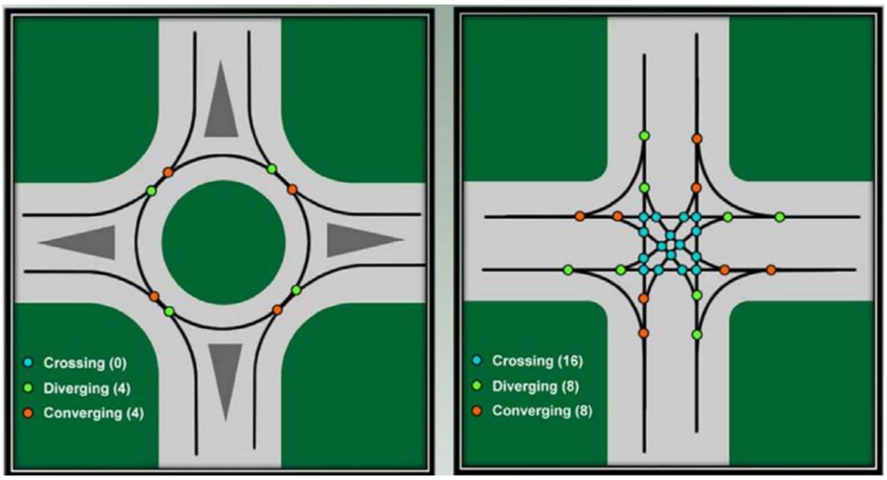
C.3 INTERSECTION CRASHES

C.3.1 ROUNDABOUT SINGLE LANE (3.01)

Roundabouts are commonly used to replace cross and T-intersections to reduce the number of right-angle crashes and those related to high speeds, both of which are factors which lead to crashes of a more serious nature. While a full roundabout conversion is among the most expensive of intersection treatments, roundabouts have significant safety advantages over cross-intersections. Roundabouts are often viewed as the ideal at-grade intersection option for improved safety based on the Safe System approach.

A roundabout inherently has fewer conflict points than other intersection types as shown in Figure C.18. The geometry and deflection on the approaches of the roundabout force drivers to reduce speeds to safely negotiate the roundabout, reducing the risk of serious crashes. However, the number of low-angle impact crashes and rear-end crashes may increase.

Figure C.18: Comparison of roundabout and 4-leg intersection conflict points



Source: FHWA (n.d.).

Roundabouts may induce a higher number of cyclist-involved crashes especially in multilane environments. Provisions for cyclists, either by the use of on or off-road facilities, can reduce the risk to cyclists. Pedestrians can be at greater risk at roundabouts; however, as indicated in Austroads (2015c), a well-designed roundabout does not increase the risk to pedestrians especially one-lane roundabouts.

The CRFs for converting at-grade intersections to a one-lane roundabout identified from recent international literature are presented in Table C.61, with a weighted average of 75% reduction in casualty crashes. The weighted average was calculated based on the values related to casualty crashes.

A summary of the CRFs specified by jurisdictions and the computed values from recent literature sources are provided in Table C.62. The Austroads 2017b (2012a) evaluation of the Federal Blackspot Program reported crash reductions of roundabouts to be 70% for casualty crashes and 50% for the crashes involving property damage only. VicRoads adopted 70% and 80% forreductions in casualty crashes in urban and rural areas respectively. Similarly, Main Roads Western Australia (MRWA) specified 55% and 70% reductions in casualty crashes in urban and rural areas respectively.

Note that Queensland and South Australian CRFs indicate an increase in pedestrian crashes, while NSW and WA CRFs indicatereductions in pedestrian crashes. As stated above, Austroads (2015c) indicates that a well-designed roundabout does not increase the risk for pedestrians. As a result, the CRF for pedestrian risk was reviewed.

Table C.61: CRFs from recent literature for converting an intersection to a one-lane roundabout (% reduction)

Reference	Casualty crashes	All crashes	Comments
Qin et al. (2013)	18.2 (3 stars) *	35.98 (4 stars)	Intersection to single-lane roundabout
Jensen (2017)		25 (3 stars)	
		48 (3 stars)	
Abdel-Aty et al. (2014)	71 (4 stars)		Signalised intersection to single- or multi-lane roundabout
Isebrands (2012)	87 (4 stars)		High-speed rural intersection to roundabout
Sun et al. (2018)		72 (3 stars)	Intersection with minor-road stop control to modern roundabout**
Uddin et al. (2012)	60 (3 stars)		Intersection to modern roundabout**
Weighted average	75		

** Outlier excluded from weighted average.*

*** A modern roundabout is an unsignalised one-way circular intersection engineered to maximise safety and minimise traffic delay.*

Table C.62: Summary of CRFs for converting an intersection to a one–lane roundabout (% reduction)

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	85	85			75			
2	Head-on	70	35			70			
3	Opposing vehicles turning	85	85			70			
4	Rear-end	-20	-20			-20			
5	Parallel lanes turning	-	-20			-20			
6	U-turn	50	70						
7	Hit pedestrian	-30	65		60	-30			
8	Out of control, on curve	-				-140			
9	Casualty crashes, all environments	-						70 (2010)	75
10	Urban	-		70	55			55 (2010)	
11	Rural	-		80	70			70 (2010)	
	Treatment life (years)	20		25		20		10 years +	

There were generally consistent results from the recent literature and current domestic practice. Therefore only minor changes to the existing CRF values from the matrix were made (Table C.63).

Table C.63: Summary of changes to CRFs for converting an intersection to a one-lane roundabout (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	85	85	75	85
2	201, 501	Head on	70	70	70	70
3	202 - 206	Opposing vehicles turning	85	85	75	85
4	301 - 303	Rear end	-20	-20	-20	-20
7	207, 304	U-turn	50	50	50	50
12	001 - 009	Hit pedestrian	-30	-30	-30	-30

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
16	703, 704, 904	Off carriageway on straight, hit object			-20	-20
18	801, 802	Off carriageway, on curve			-40	-40
19	803, 804	Off carriageway on curve hit object			-20	-20

C.3.2 ROUNDABOUT – TWO-LANE (3.02)

The CRFs for converting at-grade intersections to two-lane roundabouts identified from recent international literature are presented in Table C.64. Most of the reported CRFs are based on all crashes and vary widely and have been excluded in the weighted average. The only CRF forcasualty crashes relevant to this treatment is 63%, rounded to 65% as the weighted average. Note that the 44% CRF was excluded from the calculation of the weighted average since it was related to the conversion from an intersection to any type of roundabout.

A summary of the CRFs used by jurisdictions and the computed values fromrecent literature sources are provided in Table C.65. It is noted that this treatment could potentially lead to an increase in rear-end, lane-change and parallel-lanes-turning crashes. Queensland and South Australian CRFs indicate an increase in pedestrian crashes, while NSW and WA CRFs indicate reductions in pedestrian crashes. Austroads (2015a) reported that a well-designed roundabout, especially aone-lane roundabout does not increase the risk for pedestrians.

Table C.64: CRFs from recent literature for converting intersections to two-lane roundabouts (% reduction)

Reference	Casualty crashes	All crashes	Comments
Qin et al. (2013)	63.28 (4 stars)	-6.23 (4 stars)	Intersection to multi-lane roundabout
Zhang and Wang (2017)		-206 (3 stars)	Traffic circle to multi-lane roundabout
		-129 (1 star)	All-way stop to multi-lane roundabout
		21 (1 star)	Two-way stop to multi-lane roundabout
		1 (1 star)	Signal to multi-lane roundabout
		20 (1 star)	Unknown to multi-lane roundabout
Elvik (2017)	44 (5 star) *		Single and double-lane roundabouts
Weighted average	65		

**Indicating the conversion to any type of roundabout.*

Table C.65: Summary of CRFs for converting at-grade intersection to a two-lane roundabout (% reduction)

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads*	Recent literature
1	Intersection, adjacent approaches	85	85			75			
2	Head-on	70	35			70			
3	Opposing vehicles turning	85	85			70			
4	Rear-end	-20	-20			-20			
5	Lane change	-20	-20						
6	Parallel lanes turning	-20	-20			-20			
7	U-turn	50	70						
8	Hit pedestrian	-30	65		60	-30			
9	Casualty crashes, all environments	-						70 (2010)	65
10	Urban environment	-		60	55			55 (2010)	

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads*	Recent literature
11	Rural environment	-		70	70			70 (2010)	
	Treatment life (years)	**20**		**25**	**20+**	**20**		**10 years +**	

** It is noted that the Austroads work did not distinguish the number of lanes at the roundabout. However, a 40% CRF is noted for converting a two-lane roundabout to a one-lane roundabout.*

There were generally consistent results from the recent literature and current domestic practice. Therefore only minor changes to the existing CRF values from the matrix were adopted as in Table C.66 .

Table C.66: Summary of changes to CRFs for converting at-grade intersection to a two-lane roundabout (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	85	85	85	85
2	201, 501	Head on	70	70	70	70
3	202 - 206	Opposing vehicles turning	85	85	85	85
4	301 - 303	Rear end	-20	-20	-20	-20
5	305 - 307, 504	Lane change	-20	-20	-30	-30
6	308, 309	Parallel lanes turning	-20	-20	-30	-30
7	207, 304	U-turn	50	50	50	50
12	001 - 009	Hit pedestrian	-30	-30	-30	-30
16	703, 704, 904	Off carriageway on straight, hit object			-20	-20
19	803, 804	Off carriageway on curve hit object			-20	-20
20	805 - 807	Out of control, on curve			-40	-40

C.3.3 CLOSURE – ONE LEG OF X-INTERSECTION (3.03)

Street closures are a very effective method of eliminating crash risk. Austroads (2015a) stated that road closures are normally done as part of local area traffic management initiatives to restrict and divert traffic to chosen traffic-carrying roads, away from local access streets. At intersections, road closures can be used to direct turning traffic to higher-quality turning facilities at adjacent intersections. They can also sever the connectivity through an area and force the traffic to use other more appropriate routes. The closures can be achieved by erecting a simple barrier, extension of a median, or in many cases, by turning part of the road into a landscaped nature reserve. As a result, street closures can reduce all types of intersection and midblock crashes on affected roads. The BITRE (2012a) evaluation of the national blackspot program reported a 30% reduction in crashes, but the original source of this value is unknown.

Limited recent literature was available which provided CRFs for the closure of one leg of an intersection. The CRFs for closing one leg of a cross-intersection identified from the available international studies are presented in Table C.67. One of the values sourced is related to vehicle and bicycle crashes, which is inconsistent with the jurisdiction CRFs for this treatment. Accordingly, it has been excluded from the weighted average calculation and is provided for information only.

A summary of the CRFs for the jurisdictions and the computed values from recent literature are provided in Table C.68.

Table C.67: CRFs from recent literature for street closure – one leg of x-intersection (% reduction)

Reference	All crashes	Comments
Xie et al. (2013)	25 (2 stars)	All crashes in urban locations (compared 3-leg against 4-leg signalised intersections)
Miranda-Moreno et al. (2011)*	13.8 (3 stars)	All crash types involving vehicle/bicycle in urban and suburban locations

Reference	All crashes	Comments
Weighted average	25	

** Excluded from weighted average due to vehicle/bicycle crashes only.*

Table C.68: Summary of CRFs for street closure – one leg of x-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	70	70			50			
2	Opposing vehicles turning	70	70			50			
3	Rear-end	50	50						
4	Hit pedestrian	30	30			50			
5	Out of control, on curve	-				10			
6	All crashes	-							25
	Treatment life (years)	**20**							

Based on the limited information available on this particular treatment, the workshop attendees agreed to leave the existing CRFs unchanged and introduce an increase in U-turn crashes to account for the potential redistribution of traffic. The changes to the TMR matrix are summarised in Table C.69.

Table C.69: Summary of changes to CRFs for street closure – one leg of xintersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	70	70	70	70
3	202 - 206	Opposing vehicles turning	70	70	70	70
4	301 - 303	Rear end	50	50	50	50
7	207, 304	U-turn			-20	-20
12	001 - 009	Hit pedestrian	30	30	30	30

C.3.4 STREET CLOSURE – T-INTERSECTION (CLOSE STEM OF TEE) (3.04)

No relevant CRFs were sourced from recent international literature for street closure – T-intersection. The Bureau of Infrastructure, Transport and Regional Economics (2012a) evaluation of the national blackspot program reported a 65% reduction in crashes, but the original source of this value is unknown.

A summary of the CRFs used by jurisdictions is provided in Table C.70. The values indicate that the closure of the T-intersection almost eliminates adjacent-approaches and opposing-turn crashes, however, the effect further downstream from the redistribution of turn movements is not captured in the CRFs.

Table C.70: Summary of CRFs for street closure – T-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	100	95			100			
2	Opposing vehicles turning	100	95			100			
3	Rear-end	75							
4	Parallel lanes turning	100							
5	Hit pedestrian	50	95			50			
6	Out of control, on curve	-				10			
	Casualty crashes								65
	Treatment life (years)	**20**							

With limited literature on the treatment available, workshop attendees decided to make only minor changes to the CRFs, scaling back the values slightly (Table C.71).

Table C.71: Summary of CRFs for street closure – T-intersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	100	100	90	90
3	202 - 206	Opposing vehicles turning	100	100	90	90
4	301 - 303	Rear end	75	75	75	75
6	308, 309	Parallel lanes turning	100	100	90	90
12	001 - 009	Hit pedestrian	50	50	30	30

C.3.5 GRADE SEPARATION OF INTERSECTION (3.05)

One of the most effective ways to improve safety at an intersection is to separate conflicting vehicle movements using grade separation. This reduces the number of conflict points reducing the overall intersection crash risk. This is achieved by the use of overpasses and interchanges (Figure C.19). The use of grade separation can also improve the flow of traffic.

Grade separation with interchanges and overpasses is typically used as part of freeway systems where there are large traffic flows to justify the high cost. The use of on-ramps and off-ramps can increase weaving and merging manoeuvres and result in crashes.

Figure C.19: Grade separation of an intersection

Source: Austroads (2015a).

Limited CRFs were sourced for grade separation of intersections identified from recent international literature. The only CRF of 58% was derived from a US-based study which was related to diverging diamond interchanges with extremely limited application.

Austroads reports specified the following:

- 50% reduction in casualty crashes (Austroads 2010)
- reductions of 55% and 20% for converting cross-intersections and Y-junctions respectively (Austroads 2015a).

A summary of the CRFs used by jurisdictions and the computed values from recent literature are provided in Table C.72. The values suggest that this treatment is most successful at removing the adjacent-approach crashes.

Table C.72: Summary of changes to CRFs for grade separation of intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads (2012)	Recent literature
1	Intersection, adjacent approaches	100				100			
2	Opposing vehicles turning	100				50			
3	Parallel lanes turning	50				20			
4	Hit pedestrian	70				70			
5	Out of control, on curve	-				50			
	All crashes	-							60
	All casualty crashes	-		50				55 (x-int) 20 (Y-int)	
	Treatment life (years)	**20**		**25**					

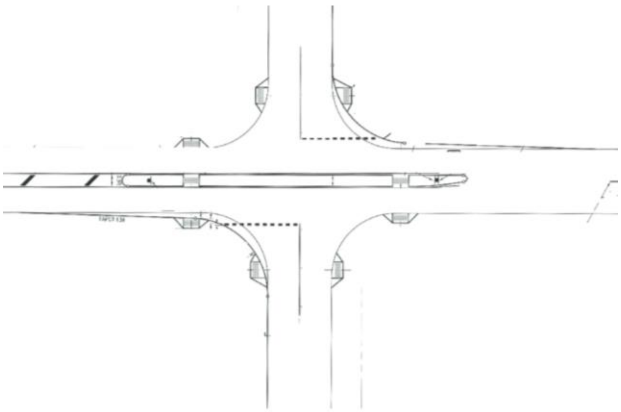
While grade separation has significant safety benefits, given its substantial capital investment it is not typical that a grade separation would be installed on purely safety grounds and therefore it is unlikely that the CRF matrix would be used in this context.

Accordingly, it was proposed to remove the grade separation treatment from the matrix.

C.3.6 MEDIAN CLOSURE (EXTENDED MEDIAN THROUGH INTERSECTION) (3.06)

This treatment involves the extension of the central median through the intersection to prevent right-turning movements (also referred as 'left-in, left out' treatment). An example of median closure is shown in Figure C.20.

Figure C.20: Median closure



Source: MRWA (2019).

No CRFs were sourced from recent literature for median closure via extension of the central median. Similarly, no values were available from the Austroads reports.

A summary of the CRFs used by jurisdictions is provided in Table C.73 The CRFs used by SA and NSW differ from TMR, however the values indicate it is effective in removing/reducing adjacent-approaches and opposing-turn crashes.

Table C.73: Summary of CRFs for median closure (extended median through intersection) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	100	85			75			
2	Head-on	30(L), 20(H)	60			100			
3	Opposing vehicles turning	100	85			100			

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
4	Rear-end	50	40						
5	Parallel lanes turning	50	85						
6	U-turn	100	85						
7	Overtaking, same direction	100	95						
8	Hit pedestrian	40(L), 30(H)				50			
	Treatment life (years)	20							

Given the lack of literature identified for this treatment, the updates to this CRF were based on local practice and expert opinion of workshop attendees. It is noted in particular that, while two jurisdictions demonstrated a significant reduction in U-turns as a result of this treatment (100% and 85%), it was recognised by the working group that this benefit is likely to be localised, and that the treatment is likely to simply redistribute U-turn traffic to another point in the road. Hence, a lower value for this CRF was adopted (Table C.74).

Table C.74: Summary of changes to CRFs for median closure (extended median through intersection) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	100	100	85	85
2	201, 501	Head on	30	20	60	60
3	202 - 206	Opposing vehicles turning	100	100	90	90
4	301 - 303	Rear end	50	50	60	60
6	308, 309	Parallel lanes turning	50	50	50	50
7	207, 304	U-turn	100	100	20	20
9	503, 505, 506	Overtaking, same direction	100	100	90	90
12	001 - 009	Hit pedestrian	40	30	30	30

C.3.7 STAGGER X INTERSECTION (X INTO STAGGERED T, L/R CONFIGURATION) (3.07)

A more involved geometric intersection treatment is the conversion of a cross-intersection into a staggered T-intersection, whereby the two minor-road approaches to the intersection are offset with respect to each other. This treatment effectively decreases the number of conflict points and encourages slower speeds, which further reduces the likelihood of a serious injury. Staggered T-intersections are moderately effective in reducing crashes from adjacent directions at low-volume unsignalised intersections.

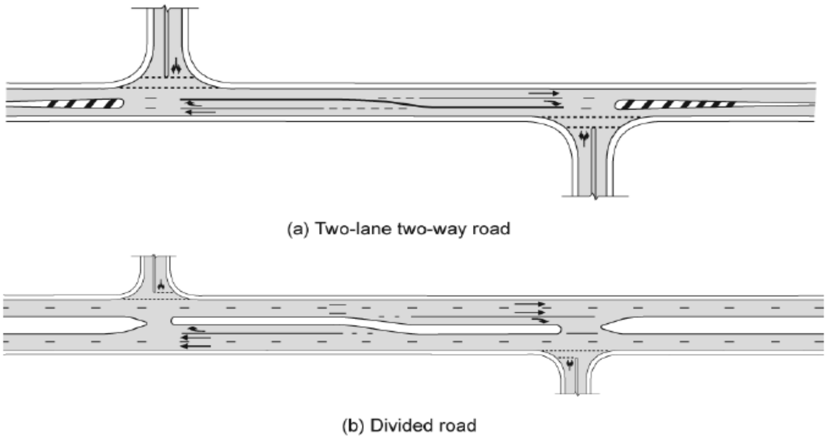
There are two types of staggered T-intersections:

- the left-right stagger, where traffic arriving at the intersection undertakes a left turn followed by a right turn to cross the major road (Figure C.21)
- the right-left stagger, where traffic takes a right turn followed by a left turn to cross the major road.

Consideration should be given to the volume of traffic on the minor road undertaking the through movement at the existing cross-intersection. It may be safer for the intersection to remain as it is.

This treatment should not be provided where traffic analysis indicates that the intersection is likely to operate at or near capacity within the early years of its design life (Chia et al. 2013)

Figure C.21: Left-right staggered T-intersections



Source: Austroads (2017a).

No updated CRF values were identified from recent literature. A summary of the CRFs used by jurisdictions is provided in Table C.75. Austroads (2010) reported the following CRFs for casualty crashes:

- 35% increase (CRF = -35%) if minor road traffic is less than 15%, but 25% to 35% reduction for minor road traffic greater than 15%
- reductions of 40–80% for adjacent approaches; 40-80% head-on; 40-60% opposing vehicles turning; 40-60% hit pedestrian and 60-80% rear-end.

Table C.75: Summary of CRFs for converting x intersection into staggered T, L/R configuration (% reduction)

No.	Crash type (DCA Group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads (2010)	Recent literature
1	Intersection, adjacent approaches	100	95		55	70		40-80	
2	Head-on	30(L),20(H)						40-80	
2	Opposing vehicles turning	-	-10		55	50		40-60	
3	Rear-end	-10	-10			-30		60-80	
4	Lane change	-				-10			
5	Hit pedestrian	-				20		40-60	
6	Casualty crashes	-		40			35	25-35	
	Treatment life (years)	**20**							

Note: L = less than 80km/h, H = greater than or equal to 80km/h

The CRFs in the matrix were revised to better align with the identified literature – particularly from Austroads – and domestic practice (Table C.76).

Table C.76: Summary of changes to CRFs for converting x-intersection into staggered T, L/R configuration (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	100	100	70	70
2	201, 501	Head on			-20	-20
3	202 - 206	Opposing vehicles turning			50	50
4	301 - 303	Rear end	-10	-10	-20	-20
5	305 - 307, 504	Lane change			-40	-40

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
6	308, 309	Parallel lanes turning			-20	-20
7	207, 304	U-turn			-20	-20
12	001 - 009	Hit pedestrian			20	20

Additionally, it was noted that while a left-right stagger is typically preferred – particularly in an urban context – the provision of a right-left stagger may also offer benefits. Right-left staggers may be preferable in a high-speed rural context as it ensures that minor-road traffic spends as little time on the main road as possible. Consideration of site-specific constraints is needed.

Accordingly, the right-left stagger has been included in the revised CRF matrix (Table C.77).

Table C.77: Summary of CRFs for converting x-intersection into staggered T, R/L configuration (% reduction)

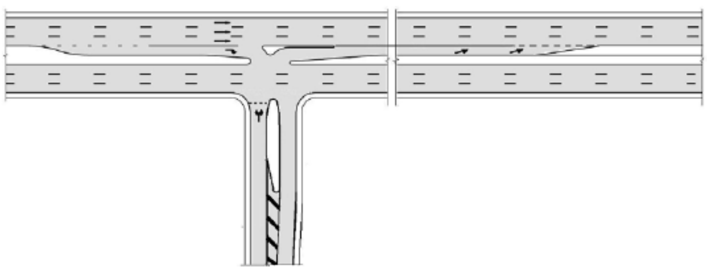
DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches			30	30
3	202 - 206	Opposing vehicles turning			50	50
4	301 - 303	Rear end			20	20
5	305 - 307, 504	Lane change			-40	-40
6	308, 309	Parallel lanes turning			-20	-20
12	001 - 009	Hit pedestrian			20	20

C.3.8 SEAGULL ISLAND WITHOUT ACCELERATION LANE, RAISED ISLAND (3.08)

Seagull intersections usually function best from an operational perspective where right-turning traffic from the minor road would be delayed for extended periods due to the small number of coincident gaps on the major road, particularly if upstream events on both major road legs cause traffic to arrive at the intersection in platoons. Figure C.22 shows the layout of a seagull intersection.

However, several jurisdictions have started to avoid the use of this treatment especially in a high-speed environment, therefore a more detailed study should be conducted for this treatment to review its benefit in practice.

Figure C.22: Seagull intersection



Source: Austroads (2017a).

The CRFs for the seagull intersection layout without acceleration lanes identified from recent international literature are presented in Table C.78. The only study showed a very minimal effect in reducing crashes and suggested an increase in vehicle/bicycle type crashes resulting from this treatment.

Austroads (2012) reported an increase of 6% and 2% for all crashes and casualty crashes, respectively for seagull intersections based on a single study.

A summary of the CRFs used by jurisdictions is provided in Table C.79. SA was the only other jurisdiction to report values for this treatment, with CRFs of 30 and 40 for opposing-turns and rear-end crashes respectively.

Table C.78: CRFs from recent literature for seagull island without acceleration lane, raised island (% reduction)

Reference	All crashes	Comment
Schepers et al. (2011)	4 (2 stars)	Installation of additional travel lanes, a raised island and left-turn lane
	-10 (2 star) *	For vehicle/bicycle only. Installation of additional travel lanes and a raised island

**As this is for vehicle/bicycle only, this value has been excluded from the weighted average.*

Table C.79: Summary of CRFs for seagull island without acceleration lane, raised island (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10							
2	Head-on	30(L),20 (H)							
3	Opposing vehicles turning	40				30			
4	Rear-end	60				40			
5	Lane change	40							
6	Parallel lanes turning	10							
7	U-turn	15							
8	Overtaking, same direction	100							
9	Hit pedestrian	25							
	All crashes							-2	5
	Treatment life (years)	**15**							

While the literature was limited, recent Austroads work noted an increase in all casualty crashes associated with seagull-style treatments. As a result this treatment type has been removed from the matrix.

C.3.9 SEAGULL ISLAND WITH ACCELERATION LANE, RAISED ISLAND (3.09)

Only one study was sourced for the use of a seagull island with an acceleration lane and a raised median (Table C.80). The reported CRF is for crashes involving bicycles and vehicles only, hence it is not used in the matrix; nevertheless this treatment should be reviewed in a detailed study to determine its benefit.

A summary of the CRFs used by jurisdictions is provided in Table C.81. NSW was the only other jurisdiction to report CRF values for this treatment.

Table C.80: CRFs from recent literature for seagull island with acceleration lane, raised island (% reduction)

Reference	All crashes	Comment
Schepers et al. (2011)	-48 (2 stars)	Installation of raised island and left-turn lane, vehicle and bicycle interactions

Table C.81: Summary of CRFs for seagull island with acceleration lane, raised island (% reduction)

No.	Crash type (DCA gGroup)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20	25						
2	Head-on	30(L),20(H)	25						

No.	Crash type (DCA gGroup)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
3	Opposing vehicles turning	40	25						
4	Rear-end	60	50						
5	Lane change	40	40						
6	Parallel lanes turning	40	40						
7	U-turn	15	15						
8	Entering roadway	100							
9	Overtaking, same direction	-	65						
10	Hit pedestrian	25	30						
11	Off carriageway	-	30						
	Treatment life (years)	**15**							

While no literature was identified for this specific seagull-style treatment , recent Austroads work has noted an increase in all casualty crashes associated with such treatments. As a result this treatment type has been removed from the matrix.

C.3.10 SEAGULL ISLAND WITHOUT ACCELERATION LANE, PAINTED ISLAND (3.10)

No updated CRF values were identified from recent literature for seagull island treatments without an acceleration lane with a painted median. No values were provided by other jurisdictions or in Austroads reports, and the only jurisdiction that provided CRFs for this particular treatment is TMR as shown in Table C.82.

Table C.82: Summary of CRFs for seagull island without acceleration lane, painted island (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10							
2	Opposing vehicles turning	40							
3	Rear-end	60							
4	Lane change	40							
5	Parallel lanes turning	10							
6	U-turn	15							
7	Overtaking, same direction	70							
8	Hit pedestrian	15							
	Treatment life (years)	**5**							

While no literature was identified for this specific seagull-style treatment variant, recent Austroads work noted an increase in all casualty crashes associated with such treatments. Therefore this treatment type has been removed from the matrix.

C.3.11 SEAGULL ISLAND WITH ACCELERATION LANE, PAINTED ISLAND (3.11)

No updated CRF values were identified from recent literature for seagull island treatments with an acceleration lane with a painted island. A summary of the CRFs used by jurisdictions is provided in Table C.83. NSW was the only other jurisdiction with CRFs for this treatment.

Table C.83: Summary of CRFs for seagull island with acceleration lane, painted island (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20	20						
2	Head-on	-	15						
3	Opposing vehicles turning	40	20						
4	Rear-end	60	50						
5	Lane change	40	40						
6	Parallel lanes turning	40	40						
7	U-turn	15							
8	Overtaking, same direction	70	55						
9	Hit pedestrian	15	15						
	Treatment life (years)	**5**							

While no literature was identified for this specific seagull-style treatment , recent Austroads work has noted an increase in all casualty crashes associated with such treatments. Therefore this treatment type has been removed from the matrix.

C.3.12 LEFT-TURN ACCELERATION LANE (3.12)

Left-turn acceleration lanes are provided to reduce crashes between vehicles entering high-speed roads and through vehicles. This treatment is preferably utilised at highway entrances that experience a high proportion of rear-end crashes, and have inadequate sight distance or high volumes of large vehicles entering the highway (FHWA n.d.).

No CRFs could be sourced from recent literature for left-turn acceleration lanes. Nevertheless, a US-based study suggested a CRF of 45% by improving sight distance through implementing modifications on existing right-turn lanes (the equivalent of left-turn lanes in Australia).

A summary of the CRFs used by jurisdictions is provided in Table C.84.

Table C.84: Summary of CRFs for installing left-turn acceleration lane (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	80				10			
2	Opposing vehicles turning	-				15			
3	Rear-end	40	30			40			
4	Lane change	40	30						
5	Parallel lanes turning	-	30						
6	Entering roadway	10							
	Treatment life (years)	**20**				**20**			

While the literature was limited, in line with the values from South Australia and the discussions by workshop attendees, it was decided that the existing safety benefits recorded for this treatment – particularly for intersection crashes – were overstated. Accordingly, revised CRFs were proposed, which are reflected in the revised matrix (Table C.85).

Table C.85: Summary of changes to CRFs for installing left-turn acceleration lane (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	80	80	20	20
4	301 - 303	Rear end	40	40	30	30
5	305 - 307, 504	Lane change	40	40	-30	-30
8	401, 406 - 408	Entering roadway	10	10	20	20

C.3.13 SEPARATE LEFT-TURN DECELERATION LANE (PAINTED OR CHANNELISED) (3.13)

Through-road speeds can be too high for vehicles to turn from the road safely when turn lanes are not provided. A dedicated left-turn deceleration lane can increase the capacity of intersections and roads by removing turning vehicles from the though-vehicle lane for improved intersection operations. At intersections with high capacity, adding a dedicated left-turn lane will increase mobility, as it removes stopped vehicles from through traffic. However, left-turning vehicles in these lanes are known to block the sight lines of drivers on the minor road and may increase crash risk.

No CRFs for left-turn deceleration lanes could be sourced in recent literature. Similarly, no other jurisdictions or Austroads have reported CRFs for this treatment as shown in Table C.86.

Table C.86: Summary of CRFs for separating left-turn deceleration lane (painted or channelised) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	15							
2	Rear-end	40							
3	Parallel lanes turning	40							
4	Entering roadway	10							
5	Hit pedestrian	10							
	Treatment life (years)	15							

This treatment was redefined as ‘improve sight lines for entering traffic by offsetting/channelising left-turn deceleration lane’ to remove the potential ambiguity with the previous treatment. The revised CRFs are shown Table C.87.

Table C.87: Summary of CRFs for improving sight lines for entering traffic by offsetting/chanellising left-turn deceleration lane (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	30	30
4	301 - 303	Rear end	40	40	-	-
6	308, 309	Parallel lanes turning	40	40	-	-
8	401, 406 - 408	Entering roadway	10	10	10	10
12	001 - 009	Hit pedestrian	10	10	-	-

C.3.14 MOVE LIMIT FORWARD USING KERB EXTENSIONS ON PRIORITY ROAD (3.14)

Austroads (2015a) specified that kerb extensions (also referred to as 'build-outs') are localised road width changes at intersections or midblocks, which extend the footpath into and across parking lanes or shoulders to the edge of the traffic lane. No part of the extension should protrude into any lane which is used by moving traffic (including cyclists) at any time.

A typical example of a kerb extension is shown in Figure C.23. They are designed to offer safety to pedestrians by reducing the width needed to cross and also provide traffic calming benefits (FHWA 2005). There is an intrinsic safety value if motorists drive slower, since build-outs induce drivers to drive slower. However, if not designed properly, this treatment may lead to an increase in rear-end crashes. (FHWA 2005).

Figure C.23: Kerb extension at intersection

Source: FHWA (2005).

The only recent Australian study by Makwasha et al. (2017) suggested a 55% reduction in casualty crashes by implementing kerb extensions at intersections or midblocks, with moderate reliability.

A summary of the CRFs used by jurisdictions is provided in Table C.88. NSW was the only other jurisdiction to report values for this treatment. It has been noted that this treatment is very similar to Treatment 3.22 (section C.3.25). To differentiate the two treatments, Treatment 3.22 is taken to apply to midblock sections.

Table C.88: Summary of CRFs for moving limit forward using kerb extensions on priority road (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	15	30						
2	Opposing vehicles turning	-	30						
3	Entering roadway	15							
4	Hit parked vehicle	20	20						
5	Hit pedestrian	20	35						
6	All casualty crashes	-					35		55
	Treatment life (years)	**10**							

Based on the higher CRFs observed from recent literature – assessed to be of moderate reliability – it was decided by the working group that the CRFs be factored upwards. In addition, an increase in the hit permanent obstruction crash type was also introduced to account for the kerb build-out being closer to the trafficable lane.

Table C.89: Summary of changes to CRFs for moving limit forward using kerb extensions on priority road (% reduction)

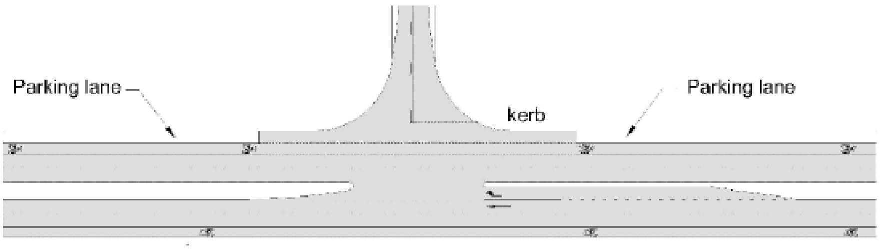
DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	40	40

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
8	401, 406 - 408	Entering roadway	15	15	-	-
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	20	20	30	30
12	001 - 009	Hit pedestrian	20	20	30	30
13	605	Permanent obstruction			-30	-30

C.3.15 UPGRADE T-JUNCTION FROM NO EXISTING TREATMENT TO CHANNELISED RIGHT-TURN TREATMENT (CHR), PAVEMENT WIDENING WITH A RIGHT 2 LANE (3.15)

A CHR treatment is implemented atexisting crossroads where there is a need to shelter turning vehicles on the major road. It allow vehicles to decelerate or stop prior to turning without effecting the flow of through traffic behind them, thus reducing the risk of rear-end crashes. It also provides a sheltered location for vehicles to wait for a suitable gap in opposing traffic before turning. A median can provide further separation between vehicles in the turn lanes and opposing traffic. The introduction of turning lanes can improve traffic flow and increase intersection capacity. Figure C.24 shows an indicative layout of an urban channelised intersection treatment.

Figure C.24: Urban channelised intersection turn treatment



Source: Austroads (2017a).

There were no updated CRF values from recent literature for a T-junction channelised right-turn treatment.

Austroads (2012) provides CRFs for right-turn lanes (type not specified) at T-intersections of 35% (urban) and 40% (rural). Since the turn-lane type is not specified, these values are provided for reference only.

A summary of the CRFs used by jurisdictions is provided in Table C.90. NSW was the only other jurisdiction with CRF values available.

Table C.90: Summary of CRFs for upgrading T-junction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right-turn lane (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20	20						
2	Head-on	-	15						
3	Opposing vehicles turning		20						
4	Rear-end	70	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	70	55						
9	Hit pedestrian	10	15						
10	Off carriageway	-	15						
	Treatment life (years)	**15**							

* *Note that the NSW CRFs are for upgrading a T-junction from no right-turn treatment/basic right turn(BAR)/auxillary right turn(AUR) toCHR/CHR(short).*

The existing CRFs for this treatment were left largely unchanged, noting their general consistency with NSW values and those for installing a turning treatment of unspecified type in the Austroads report (2012). A summary of the changes is shown in Table C.91.

Table C.91: Summary of changes to CRFs for upgrading T-junction from no existing treatment to channelised right turn treatment (CHR), pavement widening with a right turn lane (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
2	201, 501	Head on			15	15
3	202 - 206	Opposing vehicles turning			20	20
4	301 - 303	Rear end	70	70	60	60
5	305 - 307, 504	Lane change			40	40
6	308, 309	Parallel lanes turning			40	40
7	207, 304	U-turn			55	55
9	503, 505, 506	Overtaking, same direction	70	70	70	70
12	001 - 009	Hit pedestrian	10	10	10	10
15	502, 701, 702, 706, 707	Off carriageway on straight			15	15
16	703, 704, 904	Off carriageway on straight, hit object			15	15
18	801, 802	Off carriageway, on curve			15	15
19	803, 804	Off carriageway on curve hit object			15	15

C.3.16 UPGRADE T-JUNCTION FROM NO EXISTING TREATMENT TO CHANNELISED RIGHT TURN TREATMENT (CHR), PAVEMENT WIDENING WITH A RIGHT TURN LANE (ONLY RIGHT TURN AND REAR-END CRASHES) (3.42)

There were no identified CRFs for a channelised right turn treatment with pavement widening and right-turn lane (only for right-turn and rear-end crashes) sourced in recent literature. A summary of CRFs specified by TMR is provided in Table C.92 and no other jurisdiction or Austroads have reported any factors for this particular treatment. A comparable treatment from NSW is provided for reference.

Table C.92: Summary of CRFs for upgrading T-junction from no existing treatment to channelised right-turn treatment (CHR), pavement widening with a right-turn lane (only for right-turn and rear-end crashes) (% reduction)

DCA group	Crash type (DCA Group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20	20						
2	Head-on	-	15						
3	Opposing vehicles turning		20						
4	Rear-end	80	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	U-turn								
8	Overtaking, same direction	70	55						
	Overtake, turning vehicle	-	55						
9	Hit pedestrian	10	15						

DCA group	Crash type (DCA Group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
N/A	Off carriageway	-	15						
15	Off carriageway on straight								
16	Off carriageway on straight, hit object								
18	Off carriageway on curve								
19	Off carriageway on curve hit object								
	Treatment life (years)	**15**							

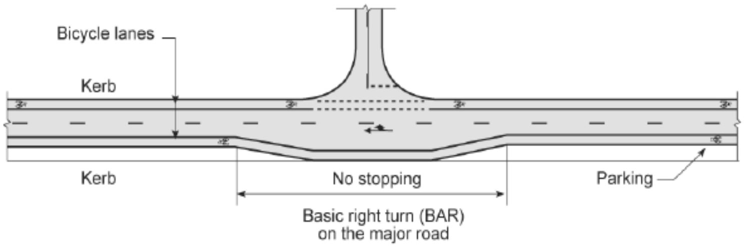
** Note that the NSW CRFs are for upgrading T-junction from no right-turn treatment/BAR/AUR to CHR/CHR(short).*

Given the overlap and potential confusion of this treatment with the preceding treatment it was decided to remove it from the matrix.

C.3.17 UPGRADING T-JUNCTION FROM BASIC RIGHT TURN (BAR) TO CHR (3.16)

The basic right-turn treatment has occasionally been applied to multilane undivided roads. It is essentially a multilane undivided road with no right-turn facility (MNR) (i.e. no separate right-turn lane) and is sometimes referred to as an MNR treatment. A layout is shown in Figure C.25.

Figure C.25: Urban basic BAR treatment



Source: Austroads (2017a).

Arndt (2004) found that MNR turn treatments recorded the highest rear-end crash rate of all the turn treatments. The study suggested that such a treatment was intuitively unsafe in the way that the central lanes of a four-lane undivided road tend to attract faster vehicles and be used for overtaking and, as a consequence, the vehicles stopped in the central lane were particularly vulnerable.

No updated CRFs for upgrading a T-junction from a BAR treatment to a CHR treatment were sourced from recent literature. A summary of the CRFs is provided in Table C.93. NSW was the only other jurisdiction with CRF values available. Note that the NSW values are for upgrading a T-junction from no right-turn treatment/BAR/AUR to CHR/CHR(short) (i.e. covers treatments 3.15 to 3.17 and 3.42 to 3.44). No other jurisdiction or Austroads have reported CRF factors for this particular treatment (Table C.93).

Table C.93: Summary of CRFs for upgrading T-junction from basic right turn (BAR) to CHR (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10	20						
2	Head-on		15						
3	Opposing vehicles turning	-	20						
4	Rear-end	40	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	40	55						

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
9	Hit pedestrian	10	15						
10	Off carriageway	-	15						
	Treatment life (years)	**15**							

** Note that the NSW CRFs are for upgrading T-junction from no right-turn treatment/BAR/AUR to CHR/CHR (short).*

Given the overlap and potential confusion of this treatment with the preceding treatments it was decided to remove it from the matrix and a single right-lane treatment be adopted.

C.3.18 UPGRADING T-JUNCTION FROM BASIC RIGHT TURN (BAR) TO CHR (ONLY FOR RIGHT TURN, REAR-END CRASHES) (3.43)

No updated CRFs for upgrading a T-junction from a BAR treatment to a CHR treatment (only for right-turn and rear-end crashes) could be sourced from recent literature. A summary of CRFs is provided in Table C.94. NSW was the only other jurisdiction with CRF values available. No other jurisdictions or Austroads have reported values for this particular treatment.

Table C.94: Summary of CRFs for upgrading T-junction from basic right turn (BAR) to CHR (only for right-turn and rear-end crashes) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10	20						
2	Head-on		15						
3	Opposing vehicles turning	-	20						
4	Rear-end	80	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	40	55						
9	Hit pedestrian	10	15						
10	Off carriageway	-	15						
	Treatment life (years)	**15**							

** - Note that the NSW CRFs are for upgrading T-junction from no right-turn treatment/BAR/AUR to CHR/CHR(short).*

Given the overlap and potential confusion of this treatment with the preceding treatments it was decided to remove it from the matrix and a single right-lane treatment be adopted.

C.3.19 UPGRADING T-JUNCTION FROM AUXILIARY RIGHT TURN (AUR) TO CHR (3.17)

Austroads (2019b) outlines that the advantages of using CHR turn treatments insteadof AUR include:

- reduction in 'rear-end major road' crashes and 'overtaking-intersection' vehicle crashes (where a right-turn vehicle is hit by an overtaking vehicle); with an AUR treatment a stationary right-turning vehicle on a tight horizontal curve or over a crest is vulnerable whereas the island in a CHR treatment guides through drivers past the right-turning vehicle
- provision of fewer types of turn treatments and thus more consistent intersection layouts
- provision of a refuge island for pedestrians crossing the major road
- increase in the average design life of turn treatments compared to AUR turn treatments; CHR(S) treatments will be able to function for longer periods before an upgrade is required
- allaying concerns from the motoring public that more CHR turn treatments should be provided on high-speed roads to improve safety.

No updated CRFs for upgrading a T-junction from AUR to CHR treatment were sourced from recent literature. Table C.95 shows the jurisdiction CRFs. NSW was the only other jurisdiction with values available. No other jurisdiction or Austroads have reported CRF factors for this particular treatment.

Table C.95: Summary of CRFs for upgrading T-junction from auxiliary right turn (AUR) to CHR

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	5	20						
2	Head-on		15						
3	Opposing vehicles turning	-	20						
4	Rear-end	30	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	30	55						
9	Hit pedestrian	10	15						
10	Off carriageway	-	15						
	Treatment life (years)	**15**							

** - Note that the NSW CRFs are for upgrading T-junction from no right-turn treatment/BAR/AUR to CHR/CHR(short).*

Based on expert opinion and the higher values observed in NSW, these CRFs were updated as shown in Table C.96.

Table C.96: Summary of changes to CRFs for upgrading T-junction from auxiliary right turn (AUR) to CHR

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	5	5	10	10
2	201, 501	Head on			5	5
3	202 - 206	Opposing vehicles turning			10	10
4	301 - 303	Rear end	30	30	30	30
5	305 - 307, 504	Lane change			20	20
6	308, 309	Parallel lanes turning			20	20
9	503, 505, 506	Overtaking, same direction	30	30	30	30
12	001 - 009	Hit pedestrian	10	10	10	10
15	502, 701, 702, 706, 707	Off carriageway on straight			10	10
16	703, 704, 904	Off carriageway on straight, hit object			10	10
18	801, 802	Off carriageway, on curve			10	10
19	803, 804	Off carriageway on curve hit object			10	10

C.3.20 UPGRADING T-JUNCTION FROM AUXILIARY RIGHT TURN (AUR) TO CHR (ONLY RIGHT-TURN REAR-END CRASHES) (3.44)

No updated CRFs for upgrading a T-junction from AUR to CHR treatment (only right-turn rear-end crashes) could be sourced from recent literature. A summary of CRFs is provided in Table C.97. No other jurisdictions or Austroads have reported values for this particular treatment.

Table C.97: Summary of CRFs for upgrading T-junction from auxiliary right turn (AUR) to CHR (only right-turn rear-end crashes) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	5	20						
2	Head-on		15						
3	Opposing vehicles turning	-	20						
4	Rear-end	80	50						
5	Lane change	-	40						
6	Parallel lanes turning	-	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	30	55						
9	Hit pedestrian	10	15						
10	Off carriageway	-	15						
	Treatment life (years)	15							

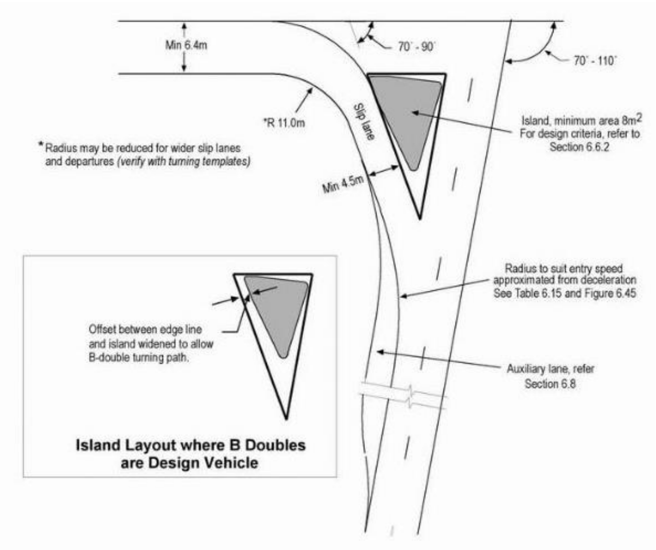
** - Note that the NSW CRFs are for upgrading T-junction from no right-turn treatment/BAR/AUR to CHR/CHR(short).*

Given its similarity to the preceding treatments it was decided that it be removed from the matrix and a single right-lane treatment be adopted.

C.3.21 CHANGING SLIP LANE FROM LOW ENTRY ANGLE TO HIGH ENTRY ANGLE (3.18)

Austroads (2002) notes that early intersection left-turn slip lanes were constructed as continuous curves between one road and the connecting crossroad. This arrangement works well only where the left- turning traffic enters an exclusive acceleration lane. When there is no added lane, the low angle of approach to the crossroad makes it difficult for drivers to see other vehicles on the crossroad. To address this problem, the slip lane is reconstructed so that it approaches the crossroad at about 70 degrees. This encourages the left-turning drivers to slow down or stop before giving way and merging into the crossroad traffic. Figure C.26 shows the layout of a slip lane with high angle entry.

Figure C.26: High angle entry slip lane



Source: Transportation Research Board (2008).

The CRFs for changing a slip lane from a low entry angle to a high entry angle from recent international literature are presented in Table C.98. The CRF weighted average has been based on one relevant value only.

No values were provided by other jurisdictions or available in Austroads reports. However, Austroads (2010) specified a 40% reduction in casualty crashes for channelisation at intersections in all environments. The only CRF specified by TMR was 50% for rear-end crashes (Table C.99).

Table C.98: CRFs from recent literature for changing slip lane (% reduction)

Reference	Left-turn crashes	All-injury crashes	All crashes	Comment
Schattler et al. (2016)*	60.3 (4 stars)	43.6 (3 stars)	44.2 (4 stars)	Improve angle of channelised right-turn lane, AADT 3300-41 000
Weighted average	60	45	50	

**US-based study, right turns are assumed to be equivalent to Australian left turns.*

Table C.99: Summary of CRFs for changing slip lane from low entry angle to high entry angle (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Rear-end	50							
2	Left turn	-							60
	Treatment life (years)	**10**							

Given that the existing values generally conform with recent literature it was decided to maintain the CRF at its existing value. The treatment life was increased to 20 years. This is shown in Table C.100.

Table C.100: Summary of CRFs for changing slip lane from low entry angle to high entry angle

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end	50	50	50	50
Treatment life			10		20	

C.3.22 MOVE LIMIT LINES FORWARD USING PAINT MARKINGS (3.19)

This treatment is similar to treatment 3.14 (Section C.3.14) with a recent Australian study (Makwasha et al. 2017) outling a 55% reduction in casualty crashes for the latter. This treatment is similar with paint taking the place of a physical buildout.

No updated CRF values were identified from recent literature or Austroads for moving limit lines forward using paint markings.

A summary of the CRFs used by jurisdictions is provided in Table C.101. NSW was the only other jurisdiction to report values for this treatment.

Table C.101: Summary of CRFs for moving limit lines forward using paint markings (% reduction)

No.	Crash type (DCA Group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10	20						
2	Opposing vehicles turning	-	20						
3	Hit pedestrian	-	20						
4	Casualty crashes	-							55*
	Treatment life (years)	**5**							

**The study was not specifically for this treatment.*

Given the higher CRFs observed for a similar treatment it was the decision of the workshop attendees to increase the values for this treatment (Table C.102).

Table C.102: Summary of CRFs for moving limit lines forward using paint markings (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	10	10	30	30
12	001 - 009	Hit pedestrian			20	20

C.3.23 INSTALL TRANSVERSE RUMBLE STRIPS ON APPROACHES (3.20)

Transverse rumble strips are raised or grooved lines across the travel lane on the approach to an intersection (Figure C.27). They provide a visual and audible warning to alert drivers of an upcoming need to act such as to slow down at an intersection.

While rumble strips warn drivers that some action may be necessary, they do not identify what action is appropriate. The driver must use visual cues to decide what type of action is needed. Thus, rumble strips serve only to supplement, or call attention to, information that reaches the driver visually. In many cases, the objective of a transverse rumble strip is to draw attention to a specific traffic control device, such as a 'stop ahead' sign (Transportation Research Board 2008).

Transverse rumble strips are most commonly used on the approach to unsignalised intersections, but have also been used on approaches to signalised intersections, particularly where there are unexpected isolated signals. Rumble strips can be noisy, and consideration needs to be given to their location relative to pedestrians, residences and other land useslocated nearby. The strips can be hazardous to motorcyclists and cyclists.

Figure C.27: Transverse rumble strips

Source: Transportation Research Board (2008).

The CRFs for installing transverse rumble strips on approaches identified from recent international literature are presented Table C.103. It is noted that the study from which the CRFs were sourced only considered crashes in rural area. The weighted averages based on casualty crashes have been adopted.

Austroads (2012) specified 25% reduction in casualty crashes with low confidence for transverse rumble strips. A summary of CRFs from jurisdictions is provided in Table C.104. However, no jurisdictions specified the treatment life for the treatment. iRAP (2010) suggests a casualty crash reduction of 10–25% for the general use of rumble strips and a treatment life of 1 to 5 years.

Table C.103: CRFs from recent literature for installing transverse rumble strips (% reduction)

Reference	Angle crashes	Rear-end crashes	Casualty crashes	All crashes
Torbic et al. (2015)	13 (3 stars) **	16 (3 stars)**	13 (4 stars) *	
	43 (3 stars) **	56 (3 stars)**	37 (3 stars)	13 (4 stars)
	25 (3 stars)	78 (3 stars)	25 (3 stars)	
	44 (3 stars)	60 (3 stars)	44 (3 stars)	18 (3 stars)

Reference	Angle crashes	Rear-end crashes	Casualty crashes	All crashes
			78 (3 stars) *	
			60 (3 stars)	
Weighted average	35	70	40	

**Outliers excluded from the weighted average.*
***Excluded as the CRF is for all crash severities.*

Table C.104: Summary of CRFs for installing transverse rumble strips on approaches (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30					25		35
2	Rear-end	70							70
3	Casualty crashes	-		2.5 (H) & 3 (L)*				25 (2012)	40
	Treatment life (years)	-							

** VicRoads specified 2.5% and 3% for speed limits of 100 km/h and 80 km/h respectively.*

Based on the international research it was decided to increase the value for the ‘intersection adjacent approaches’ CRF slightly. Other CRFs remain unchanged from existing values (Table C.105).

Table C.105: Summary of CRFs for installing transverse rumble strips on approaches (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	30	30	35	35
4	301 - 303	Rear end	70	70	70	70

C.3.24 INSTALL RAISED THRESHOLD AT CROSSING POINT (3.21)

A raised pedestrian crossing (Figure C.28) is an elevated flat-topped section of the road extending the full width of the carriageway with a formal pedestrian crossing. Only formal pedestrian crossings (zebra, pedestrian signals) should be raised to avoid any confusion regarding the priority within the road.

Raised zebra crossings are also referred to as wombat crossings. They may be considered where both traffic calming and pedestrian crossings are justified. Wombat crossings force motorists to slow down in locations where pedestrians cross, thus improving the compliance with pedestrian priority and reducing the potential impact speed in case of a crash.

Raised pedestrian crossings elevate pedestrians above the surface of the roadway and generally make them more visible to motorists. They function as an extension of the footpath and allow pedestrians to cross at a constant grade, without the need for kerb ramps or median cut-throughs.

Raised crossings may be used at intersections or midblock locations and can be implemented in association with medians or refuge islands. They should always form a part of a broader traffic calming scheme (e.g. across the neighbourhood or within a shopping centre carpark). This treatment has the following benefits:

- reduced vehicle speed
- pedestrian priority
- improved feeling of safety for pedestrians
- pedestrians encouraged to cross at one safer location
- motorists provided with an additional indication of where pedestrians might cross
- potential to discourage through traffic

- increased compliance with the zebra crossing road rule.

Figure C.28: Raised threshold at pedestrian crossing

Source: Austroads (2004).

No updated CRF values were identified from recent international literature for the treatment. Austroads (2012) specified a 20% reduction in pedestrian crashes for raised pedestrian crossings. Makwasha et al. (2017) noted several CRFs in relation to wombat crossings highlighting significant benefits for both all crash types and pedestrians specifically (60%–70%); the value for pedestrian crashes is supported by an earlier report which indicated a high robustness of the result (Sobhani et al. 2016).

A summary of CRFs is provided in Table C.106. NSW was the only other jurisdiction with CRFs for this treatment with the same values as TMR. Both jurisdictions noted an increase in rear-end crashes by introducing this treatment (Table C.107).

Table C.106: Summary of CRFs for installing raised threshold at crossing point (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30	30						
2	Opposing vehicles turning	30	30						
3	Rear-end	-10	-10						
4	U-turn	30	30						
5	Hit pedestrian	80	80					20 (2012)	70
	All crash types – casualty								60
	All crash types – FSI								65
	Pedestrian crashes – casualty								70
	Treatment life (years)	**10**							

Table C.107: Summary of CRFs for installing raised threshold at crossing point (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	30		30	30
3	202 - 206	Opposing vehicles turning	30		20	20
4	301 - 303	Rear end	-10		-	
7	207, 304	U-turn	30		-	
8	401, 406 - 408	Entering roadway			25	25

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
12	001 - 009	Hit pedestrian	80		70	70

C.3.25 MAIN-STREET TREATMENT (KERB EXTENSION/MEDIAN) (3.22)

Austroads (2015a) indicated that kerb extensions (also referred to as 'build-outs') are localised road-width changes at intersections or midblocks, which extend the footpath into and across parking lanes or shoulders to the edge of the traffic lane. This treatment is assumed to apply to midblock sections to differentiate it from similar treatments within the matrix. An example is shown in Figure C.29.

Figure C.29: Kerb extension on midblock

Source: Enacademic (2019).

The CRFs for main-street treatment (kerb extension/median) from recent literature are presented in Table C.108. The average values for FSI and casualty crashes were weighted to be 35% and 30% respectively. A summary of the CRFs used by jurisdictions is provided in Table C.109The adopted changes, informed by expert opinion and the recent literature, are outlined in Table C.110 below.

No values were provided by other jurisdictions or available in Austroads reports. Austroads (2012) reviewed a number of studies on pedestrian crash reductions but provided no recommended CRFs because all the available studies failed to adequately account for exposure.

Table C.108: CRFs from recent literature for main-street treatment (% reduction)

Reference	Casualty crashes	FSI	Head-on	Rear end	All crashes	Comment
Alluri et al. (2014)	34.1 (3 stars)	22.2 (2 stars)	70.8 (2 stars)	22.3 (3 stars)	30.3 (3 stars)	Urban and suburban
Alluri et al. (2014)	34 (3 stars)		73.5 (2 stars)	22.4 (3 stars)		Urban and suburban
Yanmaz-Tuzel and Ozbay (2010)					14 (3 stars)	Install raised median, principal arterial two-lane roads
Schultz et al. (2011)		44 (4 stars)			39 (4 stars)	
Abdel-Aty et al. (2014)	19 (2 stars)		68 (2 stars)			Urban
Abdel-Aty et al. (2014)	24 (2 stars)		71 (2 stars)			Rural
Weighted average	30	35	70	20	30	

Table C.109: Summary of CRFs for main-street treatment (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30							30
2	Head-on	-							70
3	Rear-end	-							20
4	Hit pedestrian	50							
5	Casualty crashes	-							30
6	FSI crashes	-							35
	Treatment life (years)	**15**							

The adopted changes, informed by expert opinion and the recent literature, are outlined in Table C.110 below.

Table C.110: Summary of changes to CRFs for main street treatment (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	30		-	
2	201, 501	Head on			20	
12	001 - 009	Hit pedestrian	50		40	

C.3.26 IMPROVE SIGHT DISTANCE – REMOVE IMPEDIMENTS ON MAIN ROAD (3.23)

Austroads (2017a) noted that adequate sight distance is essential to enable approaching drivers to be able to:

- recognise the presence of an intersection in time to slow down or stop in a controlled and comfortable manner
- see vehicles approaching in conflicting traffic streams and give way where required by law or avoid a crash in the event of a potential conflict.

The types of sight distances required at intersections include safe intersection sight distance and approach sight distance. Sight distance may be obstructed by road furniture, vegetation, parked vehicles, the road geometry, batters, signs etc. An example of limited sight distance due to the intersection being on the inside of a curve – accompanied by dense vegetation - is shown in Figure C.30.

Figure C.30: Sight distance limited due to intersection being on inside of curve and by vegetation

Source: FHWA (2016).

Some low-cost solutions to improve sight distance include:

- remove or cut back vegetation
- relocate structures, signs, roadside furniture impeding sight distance

- ban or indent parking
- bring the stop line forward (if safe to do so)
- install traffic mirror (low-volume, low-speed location only).

More expensive solutions may include redesigning or reconstructing the intersection (e.g. increasing the curve radii, flattening crests, flattening embankments).

No updated CRFs for improving sight distance could be sourced in recent literature. Austroads (2010) reported that sight distance improvements result in a reduction of about 30% for both the open road and at intersections. This result is reiterated in Austroads (2012).

A summary of the CRFs used by jurisdictions is provided in Table C.111. VicRoads specified a relatively higher CRF value of 55% reduction in the crashes impacted by the treatment e.g. those caused directly by obscured control signs. Moreover, the treatment life sourced from TMR is lower than what the other jurisdictions specified. This is likely due to variation in the type of obstruction being removed. For instance, a parking ban may be permanent, however the trimming of vegetation would require ongoing maintenance.

Table C.111: Summary of CRFs for improving sight distance – remove impediments on main road (% reduction)

DCA group	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	15	20	55*		30			
3	Opposing vehicles turning	15	20			30			
8	Entering roadway	30							
12	Hit pedestrian	15	20			30			
15	Off carriageway on straight								
17	Out of control on straight								
18	Off carriageway on curve								
20	Out of control, on curve	-				20			
6	Casualty crashes	-						30 (2010)	
	Treatment life (years)	**5**		**25**		**20**			

**For crashes to be saved by treatments, e.g. crashes caused directly by obscured control signs.*

Based on the literature review results and those from other jurisdictions it was decided to factor up the existing values for this treatment (Table C.112).

Table C.112: Summary of CRFs for improving sight distance – remove non-vegetative impediments on main road (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	30	30
3	202 - 206	Opposing vehicles turning	15	15	20	20
8	401, 406 - 408	Entering roadway	30	30	30	30
12	001 - 009	Hit pedestrian	15	15	20	20
18	801, 802	Off carriageway, on curve			20	20
19	803, 804	Off carriageway on curve hit object			20	20
20	805 - 807	Out of control, on curve			20	20

C.3.27 INSTALL NEW SEAL ON UNSEALED APPROACH TO SEALED ROAD (3.24)

This treatment involves sealing the unsealed approach to an intersection where the intersecting road is already sealed.

No updated CRFs for this treatment could be sourced in recent literature. Austroads (2010) specified 30% and 35% reductions for road resurfacing and shoulder sealing, respectively.

A summary of the CRFs used by jurisdictions is provided in Table C.113. A new seal will improve skid resistance, so a reduction in off-carriageway crashes may be expected, but this is not reflected in the current TMR matrix.

Table C.113: Summary of CRFs for installing new seal on unsealed approach to sealed road (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads*	Recent literature
1	Intersection, adjacent approaches	15	15						
2	Head-on	15							
3	Rear-end	30	30						
4	Off carriageway	-	30						
5	FSI crashes	-							
	Treatment life (years)	**7**							

**Austroads (2010) specified 35% and 30% reductions for road resurfacing and shoulder sealing, respectively.*

Based on its inclusion in the NSW table and its general alignment with the Austroads work, the matrix was updated to include off-carriageway crash reductions for this treatment type (Table C.114).

Table C.114: Summary of CRFs for installing new seal on unsealed approach to sealed road (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	15	15
2	201, 501	Head on	15		-	
4	301 - 303	Rear end	30	30	30	30
15	502, 701, 702, 706, 707	Off carriageway on straight			30	30
17	705	Out of control, on straight			30	30
18	801, 802	Off carriageway, on curve			30	30
20	805 - 807	Out of control, on curve			30	30

C.3.28 INSTALL NEW SIGNING – STOP SIGN AT T-INTERSECTION (3.25)

Give-way and stop signs are regulatory signs used at unsignalised intersections to control traffic movements. The signs are accompanied by prescribed linemarking in the form of appropriate holding lines (broken for give-way signs and continuous for stop signs).

Give-way and stop signs can assist in defining the priority at intersections, improve compliance with the road rules, and improve the conspicuity of the intersection. An example of a stop sign is shown in Figure C.31.

Figure C.31: Stop signs at a T-junction

Source: Austroads (2015a).

No CRFs were sourced for the installation of a new stop sign at a T-intersection from recent literature. Austroads (2012) specified a 15% reduction in casualty crashes for the treatment. A summary of the CRFs used by jurisdictions is provided in Table C.115.

Table C.115: Summary of CRFs for installing new signing – stop sign at T-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20							
2	Hit pedestrian	10							
	Casualty crashes			20				15 (2012)	
	Treatment life (years)	**10**		**15**					

Based on the Austroads (2012) work and expert opinion, the CRFs for this treatment were decreased (Table C.116).

Table C.116: Summary of changes to CRFs for installing new signing – stop sign at T-intersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	15	15
12	001 - 009	Hit pedestrian	10	10	10	10

C.3.29 INSTALL NEW SIGNING – STOP SIGN AT CROSS-INTERSECTION (3.26)

A summary of the updated CRFs for installing new stop signs at cross intersections from the literature review is provided in Table C.117. A weighted average for all crashes was calculated to be 40. Austroads (2012) specified a 30% reduction for the treatment. A summary of the CRFs used by jurisdictions is provided in Table C.118.

Table C.117: Install new signing CRFs from recent literature (% reduction)

Reference	All crashes	Comments
Haleem and Adbel-Aty (2011)	22 (3 stars)	Unsignalised 4-leg intersection with no stop signs on the minor road
El-Basyouny and Sayed (2011)	51 (4 stars)	Install two-way stop-controlled intersections at uncontrolled intersections
Weighted average	40	

Table C.118: Summary of CRFs for installing new signing – stop sign at x-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	25							
2	Opposing vehicles turning	20							
3	Hit pedestrian	15							
4	All crashes	-							40
5	Casualty crashes	-		35				30 (2012)	
	Treatment life (years)	10		15					

Based primarily on the higher values from the Austroads work, it was decided to revise the CRF values for intersection-type crashes up slightly (Table C.119).

Table C.119: Summary of changes to CRFs for installing new signing – stop sign at x-intersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	25	25	30	30
3	202 - 206	Opposing vehicles turning	20	20	20	20
12	001 - 009	Hit pedestrian	15	15	15	15

C.3.30 INSTALL NEW SIGNING – GIVE-WAY SIGN AT T-INTERSECTION (3.27)

No updated CRF values were identified from recent literature for installing new give-way signs at T-intersections.

VicRoads and Austroads (2012) specified a 15% reduction for the provision of give-way signs at all intersections. The Austroads source does not distinguish between T and cross-intersections for the installation of give-way signs. As noted in Sections 2.28 and 2.29 , there is a significant difference between the CRFs for stop signs at T and cross-intersections. Accordingly, this figure should be treated with caution. A summary of the CRFs used by jurisdictions is provided in Table C.120.

Table C.120: Summary of CRFs for installing new signing – give-way sign at T-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	15							
2	Hit pedestrian	10							
3	Casualty crashes	-		15				25 (2012)	
	Treatment life (years)	**10**		**15**					

Given the limited research, and that the existing values largely conform with the Austroads work, no changes to this treatment's CRFs were proposed (Table C.121).

Table C.121: Summary of changes to CRFs for installing new signing – give-way sign at T-intersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	15	15
12	001 - 009	Hit pedestrian	10	10	10	10

C.3.31 INSTALL NEW SIGNING – GIVE-WAY SIGN AT CROSS-INTERSECTION (3.28)

No updated CRF values were identified from recent literature for installing new give-way signs at cross-intersections.

Both VicRoads and Austroads (2012) specified a 25% reduction for the provision of give-way signs at all intersections with no differentiation between intersection types as stated in Section 2.30. Accordingly, this figure should be treated with caution.

A summary of the CRFs used by jurisdictions is provided in Table C.122.

Table C.122: Summary of CRFs for installing new signing – give-way sign at x-intersection (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	20							
2	Opposing vehicles turning	15							
3	Hit pedestrian	15							
4	Casualty crashes	-		15				25 (2012)	

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
	Treatment life (years)	**10**		**15**					

Given the limited research, and that the existing values largely conform with the Austroads work, no changes to this treatment's CRFs were proposed (Table C.123).

Table C.123: Summary of CRFs for installing new signing – give-way sign at x-intersection (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
3	202 - 206	Opposing vehicles turning	15	15	15	15
12	001 - 009	Hit pedestrian	15	15	15	15

C.3.32 INSTALL NEW SIGNING – PROHIBIT RIGHT TURN AND/OR U-TURN – PRIORITY CONTROLLED (3.29)

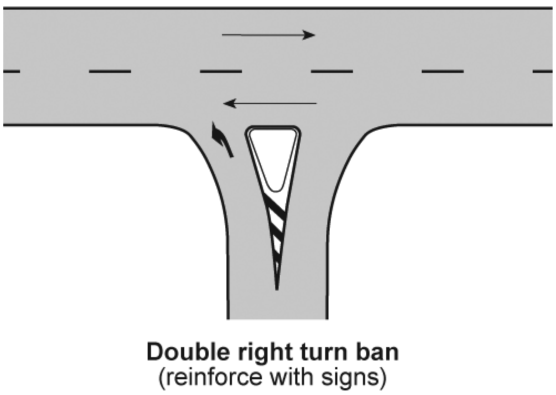
Banning or preventing traffic movements at intersections can be used to remove potential conflicts between through and turning vehicles (Figure C.32). Turn bans should be considered when all other less intrusive measures have been exhausted or found to be inappropriate. Consideration should be given to the impacts of the bans on other local streets and surrounding intersections.

Some common situations where turns are banned are outlined in Austroads (2015a), including:

- locations with a high right-turn crash rate
- too many through lanes for the right-turners to filter across (more than two usually)
- construction of a median
- poor sight distance
- lack of turning lanes in high traffic volumes
- implementation of a property access restriction strategy.

Turn bans usually involve regulatory signage but can also include changes to intersection road geometry such as triangular median islands to discourage right-turn movements to improve compliance. It is important to consider the wider network effects with this type of treatment. Banning certain movements addresses exposure to that crash risk at an intersection, but the effects in terms of net crash reductions may be lost if traffic is simply redistributed to another intersection further down the road with similar risks.

Figure C.32: Example of a right-turn-ban layout at a T-junction



Source: Austroads (2017a).

No CRF values were sourced from recent literature for right-turn and/or U-turn bans. Austroads (2012) indicates a casualty crash reduction of 60% for a right-turn ban, or a U-turn and right-turn ban. A summary of the CRFs used byjurisdictions is provided in Table C.124.

Table C.124: Summary of CRFs for installing new signing – prohibit right turn and/or U-turn – priority (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Adjacent, cross traffic	15	35						
	Adjacent, right near	15	60						
	Adjacent, other	15	20						
2	Opposing vehicles turning – right through	40	60			50			
3	Opposing vehicles turning	40	40						
4	Rear-end	60	35			50			
5	Lane change	50							
6	Parallel lanes turning	-	50			50			
7	U-turn	60							
8	Hit pedestrian	-	10						
9	Out of control, on curve	-				50			
10	All casualty crashes	-						60 (2012)	
	Treatment life (years)	**10**							

It was noted that the other jurisdictions, as well as Austroads work, pointed to significantly increased CRFs for this treatment type. As a result, the majority of CRFs were increased (Table C.125).

Table C.125: Summary of CRFs for installing new signing – prohibit right turn and/or U-turn – priority (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	15	40	40
3	202 - 206	Opposing vehicles turning	40	40	60	60
4	301 - 303	Rear end	60	60	50	50
5	305 - 307, 504	Lane change			50	50
6	308, 309	Parallel lanes turning	50	50	50	50
7	207, 304	U-turn	60	60	80	80
12	001 - 009	Hit pedestrian			10	10

C.3.33 NEW SIGNING – PROHIBIT RIGHT TURN AND/OR U-TURN – SIGNALISED (3.30)

No updated CRF values were identified from recent literature and Austroads reports for new signing (prohibit right turn and/or U-turn) – signalised. VicRoads specified a 95% reduction in all casualty crashes for right-turn bans at signalised intersections. A summary of the CRFs used by jurisdictions is provided in Table C.126.

It is important to consider with this type of treatment the wider network effects. Banning certain movements addresses exposure to that crash risk at an intersection, but the effects in terms of net crash reductions may be lost if traffic is simply redistributed to another intersection further down the road with similar risks.

Table C.126: Summary of CRFs for installing new signing – prohibit right turn and/or U-turn – signalised (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	15							
2	Head-on	40							

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
3	Rear-end	30	35						
4	Parallel lanes turning	50	50						
5	Hit pedestrian	10							
	All casualty crashes			95					
	Treatment life (years)	**10**		**25**					

At the workshop it was decided to amalgamate the two treatments rather than provide separate CRFs for signalised and priority-controlled intersections.

C.3.34 INSTALL NEW SIGNING – INTERSECTION WARNING (CAN INCLUDE FLASHING LIGHTS WITH SIGN) (3.31)

The CRFs for new intersection warning signage (including flashing lights with sign) identified from recent international literature are presented in Table C.127. In addition, a recent Australian study suggested a 35% reduction in casualty crashes (low confidence) for installing static warning signage (Makwasha et al. 2017). Austroads (2016a) specified a 60% reduction in casualty crashes for installing vehicle activated signs.

Given the expected differences in performance between dynamic and static intersection warning signs, consideration should be given to separating this treatment into multiple treatment types.

A summary of the CRFs used byjurisdictions is provided in Table C.128. NSW was the only other jurisdiction to report values for this treatment.

Table C.127: CRFs from recent literature for installing intersection warning signs (% reduction)

Reference	Angle crashes	Casualty crashes	All crashes	Comments
Himes et al. (2016)	30.3 (4 stars)	25.8 (5 stars)	29.6 (5 stars)	Intersection conflict warning system with a combination of overhead and advance post-mounted signs (various messages) and flasher, CRF for 2-lane intersections
Makwasha et al. (2017)		35 (low confidence as 1 star)		Install static warning signage
Weighted average	30	25		

Table C.128: Summary of CRFs for installing new intersection warning signs (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10	10						30
2	Opposing vehicles turning	20	10						
3	Rear-end	25	25						
4	Lane change	10							
5	Hit pedestrian	-	10						
	Casualty crashes							60	25
	Treatment life (years)	**10**							

Given the potential for significantly different CRFs for static and dynamic warning signs, it was decided that these should be separated into distinct treatments (Table C.129 and C.130).

Table C.129: Summary of CRFs for installing new static intersection warning signs (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	10	10	15	15
3	202 - 206	Opposing vehicles turning	20	20	15	15
4	301 - 303	Rear end	25	25	15	15
5	305 - 307, 504	Lane change	10	10	-	-

It was noted that dynamic signs are expected to be more conspicuous and provide greater crash reductions as a result. However, there is a large degree of variability in how they are implemented and therefore only a moderate CRF increase over static signs was applied (Table C.130).

Table C.130: Summary of CRFs for installing new dynamic intersection warning signs (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	10	10	30	30
3	202 - 206	Opposing vehicles turning	20	20	30	30
4	301 - 303	Rear end	25	25	30	30
5	305 - 307, 504	Lane change	10	10		

C.3.35 INSTALL ADDITIONAL PRIORITY SIGNS ON MEDIAN ISLANDS (3.32)

No updated CRF values were identified from recent literature for installing additional priority signs on median islands. A summary of the CRFs used by TMR is provided in Table C.131. No values were provided by other jurisdictions or in Austroads reports.

Table C.131: Summary of CRFs for installing additional priority signs on median islands (% reduction)

No.	Crash type (DCA Group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30(L), 20(H)							
2	Opposing vehicles turning	10							
3	Rear-end	20							
4	Overtaking, same direction	20							
5	Hit pedestrian	25							
	Treatment life (years)	10							

Given the lack of information on – or general use of – this treatment it was decided to remove it from the matrix.

C.3.36 INSTALL LIGHTING – INTERSECTION, NIGHT-TIME CRASHES ONLY (3.33)

Hallmark et al. (2008) evaluated the effectiveness of commonly adopted treatments aimed at reducing the number of night-time crashes. The study noted that street lighting can illuminate areas of an intersection where drivers require additional light so that they are able to avoid other vehicles and pedestrians while negotiating the geometry of the intersection.

The CRFs for installing lighting at intersections (night-time crashes only) identified from recent international literature are presented in Table C.132. The weighted average of 10 is based on one value only for all crashes (night-time). Moreover, a recent Australian study suggested a 35% reduction in casualty crashes for this treatment with low confidence (Makwasha et al. 2017).

A summary of the CRFs used byjurisdictions is provided in Table C.133. The values for the intersection, adjacent approaches crash type showed relatively greater variations across different jurisdictions whereas the other CRFs generally showed consistency.

Table C.132: CRFs from recent literature for installing lighting – intersection, night-time crashes only (% reduction)

Reference	All crashes	Comments
Donnell et al. (2010)	11.9 (3 stars)	All crash, all severity, night time
Weighted average	10	
Makwasha et al. (2017)	35 (low confidence as 1 star)	
Weighted average	20	

Table C.133: Summary of CRFs for installing intersection lighting (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads
1	Intersection, adjacent approaches	15(L), 20(H)		50			35 (urban), 30 (rural)	
2	Head-on	-	30					
3	Opposing vehicles turning	15(L),20(H)						
4	Rear-end	15(L),20(H)	20					
5	Lane change	15(L),20(H)	20					
6	Parallel lanes turning	15(L),20(H)						
7	U-turn	15(L),20(H)						
8	Entering roadway	15(L),20(H)						
9	Hit pedestrian	15(L),20(H)	30			20(L),25(H)		
10	Permanent obstruction	15(L),20(H)	20					
11	Hit animal	15(L),20(H)	20					
12	Casualty crashes (night-time)	-						20 (urban) (2010), 40 (rural) (2010). 50 (2012)
	Treatment life (years)	20		20		20		

Based on the Austroads values, it was decided to revise the treatments up slightly. In addition, a head-on CRF was added in line with NSW practice (Table C.134).

Table C.134: Summary of CRFs for installing intersection lighting (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	15	20	20	30
2	201, 501	Head on			20	30
3	202 - 206	Opposing vehicles turning	15	20	20	30
4	301 - 303	Rear end	15	20	20	30
5	305 - 307, 504	Lane change	15	20	20	30
6	308, 309	Parallel lanes turning	15	20	20	30

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
7	207, 304	U-turn	15	20	20	30
8	401, 406 - 408	Entering roadway	15	20	20	30
12	001 - 009	Hit pedestrian	15	20	20	30
13	605	Permanent obstruction	15	20	20	30
14	609, 905	Hit animal	15	20	20	30

C.3.37 INSTALL NEW TRAFFIC SIGNALS: FILTER TURNS ALLOWED (3.34)

The installation of traffic signals is a means of restricting conflicting flows of traffic and hence can reduce intersection crashes, particularly right-angle crashes. It can also improve pedestrian and cyclist safety.

The provision of dedicated left-turn and/or right-turn traffic signal phases can reduce the frequency of rear-end crashes, right-through crashes and right-angle crashes. At intersections without dedicated right-turn phases, drivers are required to screen/filter oncoming through traffic and then make a right-turn movement across the oncoming lane when they think it is safe to do so (Chen & Meuleners (2013)). Should a driver err in determining a safe gap, this may lead to a right-through collision which, in a high-speed environment, is potentially very serious.

The CRFs for installing new traffic signals with filter turns allowed identified from recent international literature are presented in Table C.135. A weighted average of a 30% reduction for all casualty crashes has been adopted from recent literature. Austroads (2012) reported a 30% reduction in all crashes, a 50% reduction in angle crashes, and a 30% increase in rear-end crashes, all with low confidence for new signals with or without filter turns allowed.

A summary of the CRFs is provided in Table C.136. The CRF values suggested that this particular treatment could potentially increase the number of crashes related to right through, opposing vehicles turning and rear-end.

Table C.135: Install new traffic signals CRFs from recent literature (% reduction)

Reference	All injuries	All crashes	Comments
Wang and Abdel-Aty (2014)	31.6 (4 stars)	34.4 (4 stars)	Intersections with major road.
	39.6 (3 stars)	49.8 (3 stars)	
	59.8 (3 stars)		
	-18.4 (3 stars) *		
	20.9 (3 stars)		
Sacchia et al. (2016)	21.8 (4 stars)	16 (4 stars)	Urban and suburban
Chen et al. (2012)		49 (2 stars)	Urban
Weighted average	30	35	

**Outlier excluded from the weighted average.*

Table C.136: Summary of CRFs for installing new traffic signals: filter turns allowed (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	70	70*			70		50 (2012)	
2	Opposing vehicles turning	-30	-30			50			
3	Rear-end	-20	-20					-30 (2012)	
4	Hit pedestrian	5	5			30			
5	All casualty crashes	-						30 (2012)	35
	Treatment life (years)	15		15*		15			

* *VicRoads and Austroads (2012) do not specify filter turns.*

TMR no longer supports the use of right-turn filter phases and accordingly this treatment has been removed from the matrix.

C.3.38 INSTALL NEW TRAFFIC SIGNALS: NO FILTER TURNS ALLOWED (3.35)

Although traffic signals can reduce overall crashes, this can result in an increase in some crash types such as rear-end and opposing-turn crashes if separate turning phases are not provided (no-turning arrows).

No CRFs could be sourced from recent international literature for installing new traffic signals without filter turns allowed. Austroads (2012) reported a 30% reduction in all crashes, a 50% reduction in angle crashes, and a 30% increase in rear-end crashes, all with low confidence for new signals with or without filter turns allowed.

A summary of the CRFs used by jurisdictions is provided in Table C.137, which shows that the treatment could effectively reduce some types of crashes such as intersection , right-through and crashes involving opposing vehicles turning, however it could potentially increase rear-end crashes by 20% as specified by TMR and NSW. VicRoads specified a 45% reduction in casualty crashes for new signals.

Table C.137: Summary of CRFs for installing new traffic signals: no filter turns allowed (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	70	70					50 (2012)	
2	Opposing vehicles turning	70	70						
3	Rear-end	-20	-20					-30 (2012)	
4	Lane change	30							
5	Hit pedestrian	30	30			30			
6	Casualty crashes	-		45*				30 (2012)	
	Treatment life (years)	**15**		**15**		**15**			

* *VicRoads did not specify filter turns.*

Several updates to the CRFs were proposed based on recent literature, expert opinion and current domestic practice and the summary of the changes is shown in Table C.138.

Table C.138: Summary of changes to CRFs for installing new traffic signals: no filter turns allowed (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	70	70	70	70
3	202 - 206	Opposing vehicles turning	70	70	70	70
4	301 - 303	Rear end	-20	-20	-30	-30
5	305 - 307, 504	Lane change			-10	-10
7	207, 304	U-turn			60	60
12	001 - 009	Hit pedestrian	30	30	50	50

C.3.39 INSTALL FULLY CONTROLLED RIGHT TURN WITH ARROWS (3.36)

Fully controlled right-turn phases are provided at intersections to eliminate right-turn filtering (Figure C.33). This treatment significantly reduces ‘through-right’ turn crashes at intersections and can reduce their severity throughout the intersection. It can also be used to remove conflict between right-turning traffic and pedestrians crossing the road.

Figure C.33: Right-turn signal

Source: Austroads (2015a).

iRAP (2010) indicated that this treatment may reduce the capacity of the intersection; hence, when used, consideration should be given to the introduction of other signal-phase changes to improve the capacity of the intersection. These may include allowing opposing right turns, parallel pedestrian movements, left-turn overlap movements and allowing any unopposed movements.

An Australian study suggested a 50% reduction in casualty crashes and 70% in FSI crashes by utilising this treatment, based on three overseas studies (Makwasha et al. (2017)).

A summary of CRFs is provided in Table C.139. The CRFs from different jurisdictions show consistency in some DCA groups. This treatment can effectively reduce the number of right- through, rear-end and U-turn crashes.

Table C.139: Summary of CRFs for installing fully controlled right turn with arrows (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches							45 (2012)	
1	Opposing vehicles turning	80	80	80*				60 (2012)	
2	U-turn	80		80*					
3	Hit pedestrian	30	30						
4	Casualty crashes	-						35 (2012)	50
	Treatment life (years)	**10**		**15**					

**The VicRoads reduction of 80% applies to crashes involving right-through movements and U-turns during right- turn periods.*

Based on the opinion of workshop attendees it was decided to maintain the existing CRF values for this treatment.

C.3.40 INTRODUCE RIGHT-TURN PHASE WHILE LEAVING FILTER (3.37)

No recent literature was sourced for the effectiveness of introducing a dedicated right-turn phase alongside an existing filter phase. Austroads (2012) reported a 10% reduction in casualty crashes for the provision of partially controlled right-turns.

A summary of the CRFs used by jurisdictions is provided in Table C.140. NSW was the only other jurisdiction to report values specifically for this treatment.

Table C.140: Summary of CRFs for introducing right-turn phase while leaving filter (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Opposing vehicles turning	5	5	14*					
2	Hit pedestrian	5	5						

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
3	All casualty			4				10% (2012)	
	Treatment life (years)	**10**							

**The VicRoads reduction of 14% applies to crashes involving right-through movements only during right-turn periods.*

Right-turn filter phases are no longer supported by TMR and accordingly this treatment has been removed from the matrix.

C.3.41 UPGRADE SIGNAL DISPLAY (MAST ARM/ADDITIONAL LANTERNS) (3.38)

The visibility of signals needs to be considered in the urban environment. Mast arms can be used to increase signal visibility . In high-speed environment and where visibility is poor the signals may also be accompanied by warning signs or vehicle-activated signs.

There is limited literature on upgrading signal displays (mast arm/additional lanterns). Navin et al. (2000) reported that improved signal visibility reduced rear-end crashes by 30–40%. Austroads (2012) specified a crash reduction of 5 to 55% for improved signal visibility. A summary of the CRFs used by jurisdictions is provided in Table C.141. NSW was the only other jurisdiction to report values for this treatment.

Table C.141: Summary of CRFs for signal display upgrade (mast arm/additional lanterns) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10	10						
2	Opposing vehicles turning	10	10						
3	Rear-end	25	25						30-40
4	Hit pedestrian	10	10						
5	All casualty – replace a pedestal mount with mast arm mount signal							35	
6	All casualty – increase lens size to twelve inches							5	
7	All casualty – provide additional signal head							20	
	Treatment life (years)	**15**							

Based on recent literature, it was decided to increase the rear-end CRF for this treatment slightly (Table C.142).

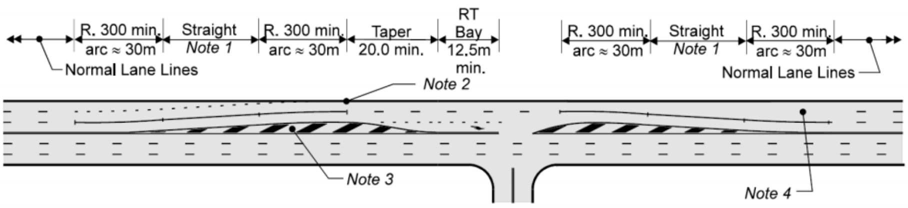
Table C.142: Summary of changes to CRFs for signal display upgrade (mast arm/additional lanterns) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	10	10	10	10
3	202 - 206	Opposing vehicles turning	10	10	10	10
4	301 - 303	Rear end	25	25	30	30
12	001 - 009	Hit pedestrian	10	10	10	10

C.3.42 S LANE TREATMENT – PROTECTED (3.39)

The S lane treatment is provided to convert an intersection with three through lanes into two through lanes with a right-turn bay as shown in Figure C.34. This treatment aims to reduce rear-end crashes and provides free-flowing conditions for vehicles in the offside through lane (adjacent to the centreline or median).

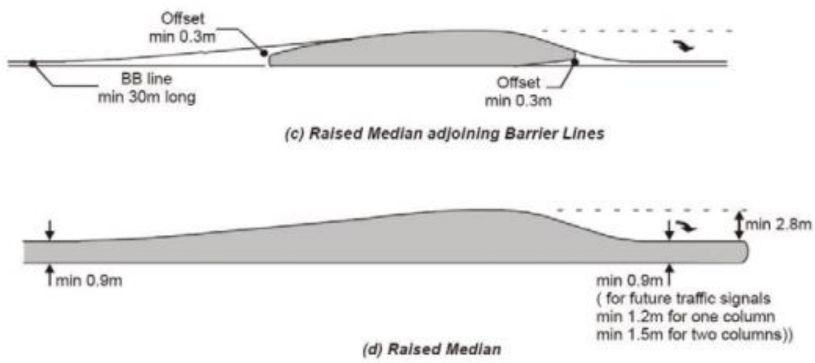
Figure C.34: S lane treatment



Source: RMS (2017).

The right-turn bay can be protected by a raised median or a raised median with adjoining barrier lines as shown in Figure C.35.

Figure C.35: Protected right-turn bays



Source: RMS (2017).

No updated CRF values were identified from recent literature for the treatment . A summary of the CRFs used by jurisdictions is provided in Table C.143. NSW is the only other jurisdiction to report values for this treatment.

Table C.143: Summary of CRFs for S lane treatment – protected (% reduction)

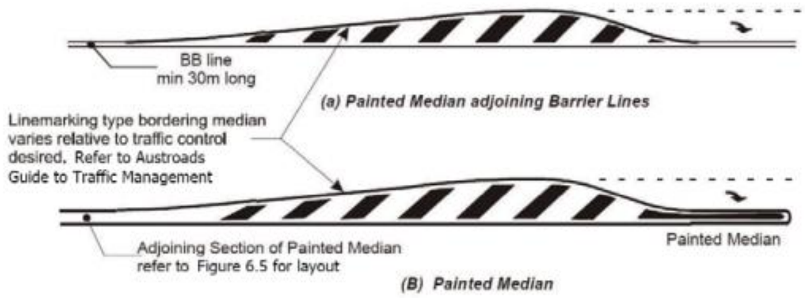
No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	-	25						
2	Head-on	10	25						
3	Opposing vehicles turning	-	25						
4	Rear-end	60	50						
5	Lane change	-	40						
6	Parallel lanes turning	40	40						
7	U-turn	-	15						
8	Overtaking, same direction	60	65						
9	Overtaking, turning vehicles	-	65						
10	Hit pedestrian	-	30						
11	Off carriageway	-	30						
	Treatment life (years)	15							

This treatment is no longer supported by TMR and has been removed from the matrix.

C.3.43 S LANE TREATMENT – PAINTED (3.40)

Right-turn bays can also be provided with protections such as a painted median or a painted median adjoining barrier lines as shown in Figure C.36.

Figure C.36: Painted S lane treatment



Source: RMS (2017).

No updated CRF values were identified from recent literature for the treatment. A summary of the CRFs used byjurisdictions is provided in Table C.144. NSW was the only other jurisdiction to report values for this treatment. Note that the NSW CRFs are different from those of TMR except for parallel lanes turning.

Table C.144: Summary of CRFs for S lane treatment – painted (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	-	20						
2	Head-on	-	15						
3	Opposing vehicles turning	-	20						
4	Rear-end	60	50						
5	Lane change	-	40						
6	Parallel lanes turning	40	40						
7	Overtake, turning vehicle	-	55						
8	Overtaking, same direction	70	55						
9	Hit pedestrian	-	15						
10	Off carriageway	-	15						
	Treatment life (years)	5							

This treatment is no longer supported by TMR and has been removed from the revised matrix.

C.3.44 INSTALL EXTENDED LENGTH OF RAISED MEDIAN (3.41)

Raised medians are often provided on urban and semi-urban roads. They are more conspicuous than painted medians and are a physical deterrent in terms of preventing cross-median manoeuvres. Raised medians can also accommodate sign posts, lighting and traffic hardware and may be landscaped to improve aesthetics and to reduce headlight glare (Austroads 2016a).

Examples of raised medians are shown in Figure C.37 and Figure C.38.

Figure C.37: Paved raised median

Source: ARRB.

Figure C.38: Grassed raised median

Source: ARRB.

The CRFs for installing extended lengths of raised median identified from recent literature are presented in Table C.145. The weighted averages for different types of casualty crashes have been adopted from the recent literature values. No values were provided by other jurisdictions or in Austroads reports, and only TMR specified CRFs for this treatment as shown in

Table C.146.

Table C.145: Install extended length of raised median CRFs from recent literature (% reduction)

Reference	Rear end	Head on	All crashes	All injuries	Comments
Zegeer et al. (2017)	27.8 (4 stars)		25.8 (4 stars)	28.6 (4 stars)	Install raised median with or without marked crosswalk (uncontrolled), urban and suburban
Schultz et al. (2011)			39 (3 stars)		Install raised median
Yanmaz-Tuzel and Ozbay (2010)			14 (3 stars)		Principal arterial, urban
Abdel-Aty et al. (2014)				19 (2 stars)	Install raised median, urban
				24 (2 stars)	Install raised median, rural
Alluri et al. (2014)	22.3 (3 stars)	70.8 (2 stars)	30.3 (3 stars)	34.1 (3 stars)	Principal arterial, urban and suburban
	22.4 (3 stars)	73.8 (2 stars)		34 (3 stars)	
Weighted average	25	75	30	30	

Table C.146: Summary of CRFs for installing extended length of raised median (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	30							
2	Head-on	-							75
3	Rear-end	-							25
4	Entering roadway	20							
5	Overtaking, same direction	90							
6	Hit pedestrian	50							
7	Off carriageway	30							
8	All injury crashes	-							30
	Treatment life (years)	**15**							

This treatment was not considered to be focused primarily on the intersection crash types. Accordingly, it was replaced with ‘install splitter islands on minor roads’. The proposed CRFs for this new treatment are outlined in Table C.147.

Table C.147: Summary of CRFs for installing splitter islands on minor roads (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches			50	50
2	201, 501	Head on			20	20
4	301 - 303	Rear end			25	25
8	401, 406 - 408	Entering roadway			10	10
9	503, 505, 506	Overtaking, same direction			-	-
12	001 - 009	Hit pedestrian			30	30
15	502, 701, 702, 706, 707	Off carriageway on straight			30	30
18	801, 802	Off carriageway, on curve			-	-
19	803, 804	Off carriageway on curve hit object			-	-

C.3.45 OTHER TREATMENTS

Other treatments worthy of discussion for inclusion in the TMR CRF matrix include signalised roundabouts and red-light cameras.

Signalised roundabouts

Signalised roundabouts are typically used at existing roundabouts that are performing poorly. Signalising a roundabout removes the potential error in judging and identifying a suitable gap to enter the roundabout. The treatment helps to improve capacity, reduce delays, reduce crashes, and address pedestrian and cyclist difficulties (MRWA 2015). Signals assist in regulating the speed of the circulating traffic which improves safety.

The increased numbers of rear-end crashes and thoseinvolving cyclists, which are inherent in a roundabout, can be controlled by the installation of part-time or full-time traffic signals . When a dominant approach is preventing traffic from another approach entering the roundabout, traffic signals could be installed to aid traffic flow and prevent congestion on the approaches. In rare circumstances where several roundabout approaches are performing poorly for extended periods, and a conventional signalised intersection is inappropriate, a roundabout may be fully signalised (Austroads 2015b).

While roundabouts offer significant safety benefits, signalisation is typically undertaken to increase the capacity, and therefore it was not considered as a direct safety intervention. Accordingly, a separate CRF was not considered necessary.

Red-light cameras

Red-light cameras, and signs informing the public of their presence, are a common treatment at signalised intersections with a high frequency of right-angle crashes attributed to drivers who intentionally disobey red lights.

While red-light cameras have the potential to decrease right-angle crashes, they can also increase rear-end crashes due to the abrupt stopping of leading vehicles and the following vehicles not having enough time to act accordingly.

Centre for Road Safety (2015) analysed the performance of the red-light camera program and reported the following crash reductions due to changes in driver behaviour:

- 34% reduction in casualty crashes
- 39% reduction in total casualties
- 55% reduction in fatalities
- 32% reduction in serious injuries
- 45% reduction in moderate injuries
- 36% reduction in minor/other injuries
- 44% reduction in pedestrian casualties.

Redlight cameras are not provided by the safety team at TMR and their inclusion in the matrix was not considered necessary.

C.4 TREATMENT FOR 'OTHER' CRASHES

As a general note, many of the treatments previously categorised under 'other' crashes related to specific vulnerable road user crash types. These treatments have been recategorised by road user group (pedestrian, cyclist or motorcyclist), although it is noted that some treatments may be relevant for more than one user group.

It is noted that the Victorian Transport Accident Commission funded an extensive project in 2017 to review pedestrian treatment CRFs, which included a review of previous Austroads work (including the 2010 and 2012 reports) as well as workshops involving experts in the field (Makwasha et al. 2017). The project report is considered the most comprehensive work in this field currently available, and for the treatments contained therein has been used as the new 'baseline' for CRFs.

C.4.1 INSTALL PAINTED LINE TO SEPARATE THROUGH AND PARKING LANE, REINFORCED WITH KERB EXTENSION (4.01)

A painted line can provide delineation, creating greater separation between parked vehicles and through traffic. This can help to reduce incidences of between through traffic and parked vehicles, as well as vehicles entering/exiting from minor roads and accesses.

TMR was the only jurisdiction to report on this treatment and no recent literature was identified. It is noted that, depending on implementation, this treatment is quite similar to 'move limit forward using kerb extensions on priority road', which was covered in the intersection workshop. The separation of through traffic from parked cars is expected to operate similarly to this treatment. During the intersection workshop a CRF of 30% was recommended for 'hit parked vehicle' suggesting that the current 60% may be overstated.

For comparison, it is noted that Austroads (2015a)[1] provides a CRF of 30% for run-off-road crashes associated with the installation of edge-lines. A summary of the CRFs is provided in Table C.148.

Table C.148: Summary of CRFs for install painted line to separate through and parking lane, reinforced with kerb extension

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
8	Entering roadway	20 (L)							
10	Hit parked vehicle	60 (L)							
12	Hit pedestrian	20 (L)							
15	Off carriageway on straight - to left	5 (L)							
16	Off carriageway on straight, hit object	5 (L)							
18	Off carriageway, on curve	5 (L)							
19	Off carriageway on curve, hit object	5 (L)							
	Treatment life	10							

Given the similarities with the following treatment (Section C.4.2) it was decided that it be removed from the matrix.

C.4.2 INSTALL PAINTED LINE TO SEPARATE THROUGH AND PARKING LANE (4.02)

This treatment is broadly similar to the previous treatment , without the supporting kerb extensions.

No supporting literature was identified. For comparison, it is noted that Austroads (2015a) provides a CRF of 30% for run-off-road crashes associated with the installation of edge-lines. A summary of the CRFs is provided in Table C.149.

[1] Austroads (2015a) expresses values as Crash Modification Factors (CMFs). For consistency, all values in this document from this source have been converted to CRFs.

Table C.149: Summary of CRFs for install painted line to separate through and parking lane

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
8	Entering roadway	20							
10	Hit parked vehicle	40							
12	Hit Pedestrian								
15	Off carriageway on straight	5							
16	Off carriageway on straight, hit object	5							
18	Off carriageway, on curve	5							
19	Off carriageway on curve, hit object	5							
	Treatment life	3							

Given the lack of supporting literature, the existing CRFs were largely maintained, however, 'hit parked vehicle' was scaled back and a new CRF of 15% was introduced based on expert opinion of workshop attendees. The changes are outlined in Table C.150 .

Table C.150: Changes to CRFs for install painted line to separate through and parking lane

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
8	401, 406 - 408	Entering roadway	20	20	20	20
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	40	40	20	20
12	001 - 009	Hit pedestrian			15	15
15	502, 701, 702, 706, 707	Off carriageway on straight	5	5	5	5
16	703, 704, 904	Off carriageway on straight, hit object	5	5	5	5
18	801, 802	Off carriageway, on curve	5	5	5	5
19	803, 804	Off carriageway on curve hit object	5	5	5	5
Treatment life			3		5	

C.4.3 INSTALL MARKED PEDESTRIAN CROSSING (ZEBRA) (4.03)

Marked pedestrian crossings – more commonly referred to as zebra crossings – highlight pedestrian crossing points to drivers as well as grant pedestrians priority at these locations, requiring drivers to yield. An example of a pedestrian crossing is shown in Figure C.39.

Figure C.39: Edge line and sealed shoulder

Source: Makwasha et al. (2017).

Makwasha et al. (2017) (also referred to later as the TAC report) noted a 30% reduction in all crash types, a 15% reduction in FSI crashes, a 75% reduction in pedestrian crashes and a 40% reduction in pedestrian FSI crashes.

It is noted in the TAC report that this treatment is generally only appropriate for low speed and low traffic volume locations, typically < 50 km/h. A summary of the CRFs is provided in Table C.151.

Table C.151: Summary of CRFs for installing marked pedestrian crossing

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads (2015a)	Recent literature
4	Rear end	-10 (L)							
8	Entering roadway								
12	Hit pedestrian	5 (L)						40	75 (L)
	All casualty crashes								30 (L)
	FSI crashes								15 (L)
	Pedestrian FSI crashes								40 (L)
	Treatment life	5							

Note: For the TMR values,L = low speed (< 80 km/h), H = high speed (≥ 80 km/h.)

Given the significantly higher CRFs in the TAC report, the outcome of the workshop was to increase the existing 'hit pedestrian' CRF. An 'entering roadway' CRF was also introduced based on the expert opinion of workshop attendees (Table C.152).

Table C.152: Summary of CRFs for installing marked pedestrian crossing

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end	-10		-10	-10
8	401, 406 - 408	Entering roadway			25	25
12	001 - 009	Hit pedestrian	5		25	25
Treatment life			5		10	

C.4.4 INSTALL PEDESTRIAN KERB EXTENSIONS, WITH MARKED PEDESTRIAN CROSSING (4.05)

By providing kerb extensions, the crossing distance for pedestrians is reduced, reducing the time they are exposed to potential conflicts with traffic. Additionally, visibility is improved both for pedestrians to cars and drivers to pedestrians. This can be especially beneficial in areas where parked cars or other sight distance obstructions exist.

No CRFs were identified for the combined use of kerb extensions with marked pedestrian crossings; however, these treatments have been reviewed separately at Sections C.4.3 and C.4.5, respectively. A summary of the CRFs is provided in Table C.153.

Table C.153: Summary of CRFs for install pedestrian kerb extensions, with marked pedestrian crossing

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	-10 (L)							
10	Hit parked vehicle	50 (L)							
12	Hit pedestrian	20 (L)							
	Treatment life	10							

Note: For the TMR values,L = low speed (< 80 km/h), H = high speed (≥ 80 km/h.)

Given the similarities with the previous treatment, it was decided not to include this in the matrix..

C.4.5 INSTALL PEDESTRIAN KERB EXTENSIONS, NO CROSSING MARKED

By providing kerb extensions, the crossing distance for pedestrians is reduced, reducing the time they are exposed to . Additionally, visibility is improved both for pedestrians to cars and drivers to pedestrians. This can be especially beneficial in areas where parked cars or other sight distance obstructions exist. An example of a pedestrian kerb extension with no marked crossing is shown Figure C.40.

Figure C.40: Pedestrian kerb extension, with no marked crossing

Source: Makwasha et al. (2017).

Makwasha et al. (2017) notes a 55% reduction in all casualty crashes, a 30% reduction in pedestrian casualty crashes and a 30% reduction in pedestrian FSI crashes. The Austroads (2012) report noted a CRF of 45%. No other recent literature was identified.

It is noted that this type of treatment was covered in the intersection workshop where a CRF of 30% was noted for 'hit pedestrian' crashes. That approach was specific to an intersection installation whereas this represents a more general approach to the treatment which can also be provided midblock. A summary of the CRFs is provided in Table C.154.

Table C.154: Summary of CRFs for install pedestrian kerb extensions, no marked pedestrian crossing

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
8	Entering roadway								
10	Hit parked vehicle	50							
12	Hit pedestrian	10					35	45	30
	All casualty crashes								55
	Pedestrian FSI								30
	Treatment life	10							

The CRFs for this treatment were revised in line with the TAC report. An additional CRF of 30% for 'entering roadway' crashes was also introduced. These changes are outlined in Table C.155 .

Table C.155: Changes to CRFs for install pedestrian kerb extensions, no marked pedestrian crossing

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
8	401, 406 - 408	Entering roadway			30	30
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	50		30	30
12	001 - 009	Hit pedestrian	10		30	30
Treatment life			10		20	

C.4.6 INSTALL PEDESTRIAN MIDBLOCK SIGNALS (4.07)

Pedestrian signals are activated when there is pedestrian demand and they stop through traffic to allow pedestrians the opportunity to cross the road. Several variations exist including standard push-button-activated crossings on set cycles and puffin crossings that use sensors to detect and extend the pedestrian phase as necessary.

An example of pedestrian midblock signals is shown in Figure C.41.

Makwasha et al. (2017) indicates a casualty crash CRF of 20% for this treatment, a pedestrian casualty CRF of 25% and a pedestrian FSI CRF of 50%. The report notes it should not be used on roads with speeds of greater than 80 km/h. A summary of the CRFs is provided in Table C.156.

Figure C.41: Pedestrian midblock signals

Source: Makwasha et al. (2017).

Table C.156: Summary of CRFs for installing pedestrian midblock signals

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear-end	-20							
8	Entering roadway								
12	Hit pedestrian	50							
	All casualty crashes								20
	Pedestrian casualty								25
	Pedestrian FSI								50
	Treatment life	10							

The existing pedestrian CRF was consistent with the TAC report. As such, it was decided to maintain this value. An additional CRF for 'entering roadway' was also introduced based on the expert opinion of workshop attendees (Table C.157).

Table C.157: Summary of CRFs for installing pedestrian midblock signals

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end	-20	-20	-30	-30
8	401, 406 - 408	Entering roadway			50	50
12	001 - 009	Hit pedestrian	50	50	50	50
Treatment life			10		20	

C.4.7 INSTALL PEDESTRIAN GRADE SEPARATION (4.08)

Pedestrian grade separation involves physically separating the pedestrian crossing point from the road by a bridge or tunnel. The treatment is most typically used where pedestrian signals would cause unacceptable delays and/or traffic speeds are high. Pedestrian grade separation can be impacted if the facility deviates significantly from pedestrian desire lines, or the facility is not maintained. The treatment should be supported by appropriate fencing and layout. The perception of personal safety can also be an issue when using tunnels. An example of an overhead bridge is shown in Figure C.42.

Makwasha et al. (2017) outlines a number of CRFs in relation to this treatment – 60% reductions in pedestrian FSI crashes and all casualty crashes. A summary of the CRFs is provided in Table C.158.

Figure C.42: Pedestrian grade separation (overhead) bridge

Source: Makwasha et al. (2017).

Table C.158: Summary of CRFs for install pedestrian grade separation

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
8	Entering roadway								
12	Hit pedestrian	90	90	85		90			70
	Pedestrian FSI								60
	All casualty crashes								60
	Treatment life	20							

Given the general conformance with the other jurisdictions it was decided to maintain the TMR CRF for this treatment at its existing value (hit pedestrian). An additional CRF of 45% for 'entering roadway' was also introduced, based on the expert opinion of workshop attendees.

Table C.159: Changes to CRFs for install pedestrian grade separation

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
8	401, 406 - 408	Entering roadway			45	45
12	001 - 009	Hit pedestrian	90	90	90	90
	Treatment life		20		50	

C.4.8 INSTALL RAILWAY LEVEL CROSSING – SIGNS (4.09)

Signing a railway crossing provides early indication to road users of its presence.

NSW and SA also provide CRFs for the installation of level crossing signage. Austroads (2015a) provides a CRF of 15% for this treatment. A summary of the CRFs is provided in Table C.160. No other recent literature was identified.

Table C.160: Summary of CRFs for install railway level crossing – signs

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
11	Hit railway train	15	20			15		15	
	Treatment life	10							

Given the general conformance with other jurisdictions and the Austroads report, and a lack of more recent literature, the existing CRF is maintained.

C.4.9 RAILWAY GRADE-SEPARATION CROSSING – BRIDGE/UNDERPASS (4.10)

A bridge or underpass provides a grade separation between the railway and the road eliminating the possibility of crashes occurring between trains and other road users. Both NSW and SA also provide CRFs for this treatment. Austroads (2015a) provides a CRF of 100. No other recent literature was identified. A summary of the CRFs is provided in Table C.161.

Table C.161: Summary of CRFs for install railway level crossing – bridge/underpass

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
11	Hit railway train	100	95			100		100	
	Treatment life	20							

Given the general conformance with other jurisdictions and the Austroads report, and a lack of more recent literature, the existing CRF is maintained.

C.4.10 INSTALL RAILWAY LEVEL CROSSING – BARRIERS (4.11)

Railway level crossing barriers – also known as boom gates – provide a physical deterrent from motor vehicles crossing the railway line when a train is approaching.

NSW and SA also provide CRFs for this treatment. Austroads (2010) indicates a CRF of 67% when converting a railway level crossing with signs to one with barriers. Austroads (2015a) indicates a CRF of 80%. No other recent literature was identified. A summary of the CRFs is provided in Table C.162.

Table C.162: Summary of CRFs for install railway level crossing – barriers

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
11	Hit railway train	80	80			80		80	
	All casualty crashes – from signs only to signs and barriers							67	
	Treatment life	20							

Given the conformance with other jurisdictions and the Austroads report, and a lack of more recent literature, the existing CRF is maintained. However, an additional 'off cariageway on straight, hit object' CRF was introduced for the potential hazard of striking the boom gates (50% increase in crashes). The treatment was also redefined as 'install railway level crossing – boom gates'".

Table C.163: Changes to CRFs for install railway level crossing – boom gates

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
11	903	Hit railway train	80	80	80	80
16	703, 704, 904	Off carriageway on straight, hit object			-50	-50
	Treatment life		20		20	

C.4.11 INSTALL RAILWAY LEVEL CROSSING — FLASHING LIGHTS (4.12)

Active traffic control systems warn road users of approaching trains. These types of warnings often consist of flashing lights accompanied by sounds (combined with static controls such a signs and pavement markings) which are triggered by a train (iRAP n.d.).

Austroads (2010) indicates a CRF of 50% for upgrading a level crossing with signage to ones with lights and bells. Austroads (2015a) indicates a CRF of 50% for 'hit train' crashes for flashing lights. No other recent literature was identified. A summary of the CRFs is provided in Table C.164.

Table C.164: Summary of CRFs for install railway level crossing – flashing lights

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
11	Hit railway train	50	50			50		50	
	All casualty							50	
	Treatment life	15							

Given the conformance with other jurisdictions and the Austroads report, the existing CRF is maintained.

C.4.12 RECESSED BAY FOR STOPPING VEHICLES (4.13)

Vehicles stopped within the through traffic lanes present a hazard to through traffic. By providing recessed bays, vehicles are able to pull out of the traffic stream safely in the event of breakdown or other emergency.

These types of bays are generally provided on high-speed roads (such as motorways) where minor roads or other potential pullover areas are infrequent.

Not recent literature on this treatment was identified. A summary of the CRFs is provided in Table C.165.

Table C.165: Summary of CRFs for installing recessed bay for stopping vehicles

Crash type (DCA Group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	5 (L), 10 (H)							
10	Hit parked vehicle	30 (L), 50 (H)							
	Treatment life	15							

Given the lack of recent literature, CRFs for this treatment were informed by the expert opinion of the workshop attendees. In light of the specific high-speed road use case, it was considered appropriate to generally increase the CRFs. This treatment was also redefined as ‘stopping bays’.

Two new CRFs were also included. These were for a reduction in pedestrian crashes (20%) to account for vehicle occupants being able to more safely exit their vehicle in the event of breakdown and an increase in crashes (30%) for entering roadway to reflect the potential hazard of vehicles re-entering the motorway (Table C.166).

Table C.166: Changes to CRFs for stopping bays

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end	5	10	30	30
8	401, 406 - 408	Entering roadway			-30	-30
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	30	50	50	50
12	001 - 009	Hit pedestrian			20	20
	Treatment life		15		20	

C.4.13 LIMIT ACCESS TO ROADSIDE DEVELOPMENT (4.14)

Accessways to adjacent properties from a road create the opportunity for conflicts as vehicles slow down to turn into an access, enter the road at lower speed, or turn across through traffic. Limiting the number of accesses onto a road can help reduce the number of these conflicts.

NSW also provides a CRF for this type of treatment, whereas WA indicates a CRF for limiting property accesses to ‘left-in, left-out’ only, reducing opportunities for cross-traffic and right-through crashes. No recent literature on this topic was identified. A summary of the CRFs is provided in Table C.167.

Table C.167: Summary of CRFs for limit access to roadside development

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
8	Entering roadway	60	60						
	Left-in, left-out only (cross-traffic and right-through crashes)				55				
	Treatment life	10							

Additionally, Austroads (2010) outlines a number of formulae for calculating the relative risk of the number of accesses along a route.

Equation A5: Relative risk of roadside development

Road type	Formulae	A5
Open-road 4 lane	1 + (0.02 x residential/km + 0.10 x commercial/km + 0.20 x minor junctions) x ({0.45 if median-solid or > 3 m}, 1 if no median)	
Open-road 2 lane	1 + (0.01 x residential/km + 0.05 x commercial/km + 0.20 x minor junctions) x ({0.45 if median-solid or > 3 m}, 1 if no median)	
Built-up 4 lane	1 + (0.01 x residential/km + 0.08 x commercial/km + 0.05 x minor junctions) x ({0.45 if median-solid or > 3 m}, 1 if no median)	
Built-up 2 lane	1 + (0.02 x residential/km + 0.10 x commercial/km + 0.20 x minor junctions) x ({0.45 if median-solid or > 3 m}, 1 if no median)	

The above relative risks can then be converted to a CRF as follows:

-1 x (100 – (100/relative risk))

It was decided in the workshop not to provide a CRF for this treatment but instead to provide the Austroads formula. This was due to the potential variation in what degree of access control is to be implemented.

C.4.14 INSTALL NEW SEAL ON UNSEALED SURFACE (4.16)

This treatment involves the sealing of a previously unsealed road. Sealing a road can remove inconsistencies in the surface, improve traction and decrease stopping distances. However, travel speeds may increase.

NSW and NZ also have CRFs for this treatment type. A summary of the CRFs is provided in Table C.168. No recent literature was identified.

Table C.168: Summary of CRFs for install new seal on unsealed surface

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	30 (H)							
15	Off carriageway on straight	10 (H)	10						
16	Off carriageway on straight, hit object	10 (H)	10						
17	Out of control, on straight	10 (H)	10						
18	Off carriageway, on curve		10						
19	Off carriageway on curve, hit object		10						
20	Out of control, on curve		10						
	All casualty						0		
	Treatment life	7							

Given the lack of recent literature, it was decided to largely maintain the CRFs from the existing matrix with several additional crash types introduced in line with similar CRFs and those in the NSW matrix. The CRF for rear-end crashes was, however, removed based on the expert opinion of workshop attendees (Table C.169).

Table C.169: Summary of CRFs for install new seal on unsealed surface

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end		30		
15	502, 701, 702, 706, 707	Off carriageway on straight		10	10	10

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
16	703, 704, 904	Off carriageway on straight, hit object		10	10	10
17	705	Out of control, on straight		10	10	10
18	801, 802	Off carriageway, on curve			10	10
19	803, 804	Off carriageway on curve hit object			10	10
20	805 - 807	Out of control, on curve			10	10
Treatment life			7		20	

C.4.15 PROVIDE CLEARWAY/PARKING RESTRICTIONS, PEAK (4.17)

Parked vehicles can obscure visibility between pedestrians trying to cross the road and through traffic. Additionally, vehicles parking and unparking can themselves be a hazard to pedestrians. This treatment is usually implemented through signage and may require enforcement.

Peak-hour parking restrictions are generally used as a capacity rather than safety improvement, allowing for additional road space to be utilised for through traffic during peak periods.

It is noted that South Australia did not distinguish between part and full-time parking restrictions, and Victoria's treatment was for a generic 'ban parking'. A summary of the CRFs is provided in Table C.170. Recent literature values are taken from Makwasha et al. (2017).

Table C.170: Summary of CRFs for provide clearway/parking restrictions, peak

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	10 (H)				20			
5	Lane change	-10 (H)							
6	Parallel lanes turning	-10 (H)							
8	Entering roadway	-10 (H))							
10	Hit parked vehicle	90 (H)				50			
12	Hit pedestrian	20				30			
	Ban parking – pedestrian casualty crashes			30					30
	Ban parking – pedestrian FSI crashes								30
	Ban parking – all casualty crashes								20
	Treatment life	10		20					

Given the general lack of recent literature, the previous CRFs were largely maintained with some adjustments made based on the expert opinion of workshop attendees (Table C.171).

Table C.171: Changes to CRFs for provide clearway parking restrictions, peak

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end		10	20	20
5	305 - 307, 504	Lane change		-10	-10	-10

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
6	308, 309	Parallel lanes turning		-10	-10	-10
8	401, 406 - 408	Entering roadway		-10	-10	-10
10	402, 404, 601, 602, 604, 608	Hit parked vehicle		90	50	50
12	001 - 009	Hit pedestrian	20	20	10	10
	Treatment life		10		10	

C.4.16 PROVIDE CLEARWAY/PARKING RESTRICTIONS, ALL HOURS (4.18)

This is the same as the above treatment butfor all hours of the day as opposed to peak- hour restrictions (Figure C.44).

Figure C.43: Parking restrictions

Source: Makwasha et al. (2017).

Makwasha et al. (2017) reported reductions of 30% in pedestrian FSI and casualty crashes and 20% in all casualty crashes. It is noted that South Australia did not distinguish between part and full-time parking restrictions. A summary of the CRFs is provided in Table C.172.

Table C.172: Summary of CRFs for provide clearway/parking restrictions, all hours

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	20, (H)				20			
5	Lane change	-10 (H)							
6	Parallel lanes turning	-10 (H)							
8	Entering roadway	-20 (H)							
10	Hit parked vehicle	90 (H)				50			
12	Hit pedestrian	20				30			
	Ban parking – Pedestrian Casualty Crashes			30				30	30
	Ban Parking -Pedestrian FSI Crashes								30
	Ban Parking – All casualty crashes								20
	Treatment life	10		20					

Note :TMR definitions: L = low speed (< 80 km/h) and H = high speed (>= 80 km/h).

Given the general lack of recent literature, the revised CRFs were informed by the expert opinion of workshop attendees (Table C.173).

Table C.173: Changes to CRFs for provide clearway/parking restrictions, all hours

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end		20	40	40
5	305 - 307, 504	Lane change		-10		-10
6	308, 309	Parallel lanes turning		-10		-10
8	401, 406 - 408	Entering roadway		-20		-20
10	402, 404, 601, 602, 604, 608	Hit parked vehicle		90	40	40
12	001 - 009	Hit pedestrian	20	20	30	30
Treatment life			10		10	

C.4.17 INSTALL LIGHTING – PEDESTRIAN CROSSING POINT (NIGHT-TIME CRASHES ONLY) (4.19)

The installation of lighting at a pedestrian crossing highlights the presence of the crossing itself as well as any pedestrians attempting to cross the road at that location.

Several jurisdictions had a CRF for this treatment type, or a similar variation. Makwasha et al. (2017) outlined the benefits of lighting for pedestrians generally as opposed to specifically at crossing points and has been included for reference. A summary of the CRFs is provided in Table C.174.

Table C.174: Summary of CRFs for install lighting – pedestrian crossing point

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature[1]
4	Rear end	20	20	601					
8	Entering roadway								
12	Hit pedestrian	30	40			60			
	All pedestrian crashes – all times			30					
	All casualty Crashes, all times								35
	FSI Pedestrian Crashes – all times								50
	FSI Pedestrian Crashes – night time								60
	Treatment life	10							

1. *These CRFs are for improved lighting generally, rather than specifically at pedestrian crossings.*

Given the higher reported CRFs in the TAC report, it was decided to increase the existing value for ‘hit pedestrian’. A new ‘entering roadway’ CRF was also introduced based on the expert opinion of workshop attendees (Table C.175).

Table C.175: Changes to CRFs for install lighting – pedestrian crossing point

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
4	301 - 303	Rear end	20	20	20	20
8	401, 406 - 408	Entering roadway			50	50
12	001 - 009	Hit pedestrian	30	30	50	50
Treatment life			10		10	

C.4.18 CAPPING ET2000 STYLE GUARDRAIL TERMINALS (BICYCLE AND MOTORCYCLE ONLY) (4.20)

Guardrail terminals can present a significant hazard to vulnerable road users such as cyclists and, in particular, motorcyclists. Capping the terminal reduces the possibility of errant riders or passengers from snagging on the end terminal.

No other jurisdiction has this style of treatment and no recent literature was identified. However, Victoria provides a CRF for 'modular impact cushions' that has been included for reference. A summary of the CRFs is provided in Table C.176.

Table C.176: Summary of CRFs for capping ET2000 style guardrail terminals

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
13	Permanent obstruction	5							
	Motorcycle casualty crashes (modular impact cushion)			15					
	Treatment life	5							

During the workshop it was decided to remove this treatment in favour of motorcycle barrier systems, sometimes known as rub-rails. An evaluation of the Victorian motorcycle blackspot program estimated a 74% reduction in motorcycle FSIs through the use of this treatment (Cairney et al. 2015).

Roadside barriers can be an effective road safety treatment for reducing the severity of run-off-road and head-on crashes by preventing vehicles from being exposed to severe crash hazards such as fixed objects (e.g.trees, utility poles), severe topography (e.g. cliffs) or on-coming traffic.

However, the very nature of barriers – being fixed objects next to the road – means they can act as hazards themselves. This is especially true for motorcyclists and bicyclists coming into contact with the upright posts supporting the barrier. By providing a motorcycle barrier system, these vulnerable road users can be protected from the upright posts.

Some additional CRFs were proposed for this new treatment; the previous CRFs (relating to capping of end barriers) are included for reference (Table C.177).

Table C.177: New CRFs for motorcycle barrier

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
13	605	Permanent obstruction	5	5	5	5
15	502, 701, 702, 706, 707	Off carriageway on straight			25	25
16	703, 704, 904	Off carriageway on straight, hit object			25	25
17	705	Out of control, on straight			25	25
18	801, 802	Off carriageway, on curve			25	25
19	803, 804	Off carriageway on curve hit object			25	25
20	805 - 807	Out of control, on curve			25	25
Treatment life			5		5	

C.4.19 REPLACEMENT OF UNSAFE DRAIN GRATES WITH AS 3996 COMPLIANT ALTERNATIVES (BICYCLE AND MOTORCYCLE ONLY) (4.21)

Drain grates can present a potential hazard to bicyclists in particular. An inappropriately located drain grate can catch the narrow wheel of a bicycle, throwing the rider off. Replacing the grate with an appropriate alternative removes this hazard.

No other jurisdictions had this CRF and no recent literature was identified. Given this, the existing value was maintained (Table C.178).

Table C.178: Summary of CRFs for replacement of unsafe drain grates with AS 3996 compliant alternatives

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
13	Permanent obstruction	5							
	Treatment life	20							

C.4.20 REPLACEMENT OF ACCESS CHAMBER COVERS IN HIGH FRICTION DEMAND LOCATIONS (E.G. CORNERS OR DECELERATION ZONES) WITH A CONCRETE INFILL CLASS D COVER (BICYCLE AND MOTORCYCLE ONLY) (4.22)

Some access chamber covers are made of steel or other materials that offer an inferior level of surface friction compared to the standard road surface. This disparity in surface friction can be a significant source of instability for two-wheeled vehicles, particularly motorcycles, in areas of deceleration/acceleration (corners, intersections).

No other jurisdictions had this treatment in their CRF tables and no recent literature was identified. A summary of the CRFs is provided in Table C.179.

Table C.179: Summary of CRFs for replacment of access chamber covers in high friction demand locations

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
15	Off carriageway on straight	10							
16	Off carriageway on straight, hit object	10							
17	Out of control, on straight	10							
18	Off carriageway, on curve	10							
19	Off carriageway on curve, hit object	10							
20	Out of control, on curve	10							
	Treatment life	15							

Given the lack of additional information , it was decided to maintain the existing CRFs.

C.4.21 CUTTING BACK TRAFFIC ISLANDS THAT REDUCE SHOULDER WIDTH TO LESS THAN 1 METRE WIDE (BICYCLE ONLY) (4.23)

Where installed inappropriately, traffic islands and other road infrastructure and furniture can be an impediment to cyclists and create pinch-points, forcing cyclists into closer proximity with the general traffic stream.

No other jurisdictions reported on this treatment type and no recent literature was identified. A summary of the CRFs is provided in Table C.180.

Table C.180: Summary of CRFs for cutting back traffic island to reduce shoulder width to less than 1 m

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	10							
9	Overtaking, same direction	10							
13	Permanent obstruction	10							
	Treatment life	20							

It was noted in the workshop that this is quite a niche treatment, relating to the elimination of a specific, constructed hazard to cyclists. It was reviewed as a broader 'shoulder widening' treatment, however given this had been covered in the 'run-off-road' crash type, the option was not pursued. Given a lack of additional information the existing CRFs maintained.

C.4.22 ESTABLISHING A BICYCLE LANE WHERE TRAFFIC VOLUMES EXCEED 10,000 VPD IN THE DIRECTION OF TRAVEL, POSTED SPEED 60 KM/H OR GREATER AND LOCATED ON THE PRINCIPAL CYCLE NETWORK OR COUNCIL TRUNK ROUTE (MAY INVOLVE POSTED SPEED REVIEW, PARKING RESTRICTIONS) (4.24)

The presence of a bicycle lane on a road allocates designated road space to cyclists providing some separation from motorised traffic, however there is limited research on the benefits of such treatments (Figure C.44). Two international studies were identified as summarised in Table C.181.

Table C.181: International literature on installation of a bicycle lane (casualty crashes)

Reference	All	Vehicle/bicycle	Notes
Chen et al. (2012)	5.4 (3 Stars)	N/A	Urban
Abdel-Aty et al. (2014)	27 (2 Stars)	60 (2 Stars)	Urban

Note: All figures relate to casualty crashes.

It is noted that the table provides a summary of the results based on casualty crash CRFs. Care should be taken when interpreting these figures. While the table presents casualty crashes only, both studies also reported on vehicle/bicycle crashes of all severities. For this crash type, Chen et al. (2012) indicated a 50% increase in crashes. This is in stark contrast to Abdel-Aty et al. (2014) which reported a 58% reduction.

A summary of the CRFs, including those from other jurisdictions, is provided in Table C.182.

Figure C.44: On-road bike lane

Source: Austroads (2015b).

Table C.182: Summary of CRFs for establishing a bicycle lane where traffic volumes exceed 10,000 vpd

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
4	Rear end	10							
9	Overtaking, same direction	10							
13	Permanent obstruction	10							
	On-road bike path			30	0				
	All crashes (bicycles)				13				
	Lanes < 1.4 m wide – all crashes						10		
	Lanes > 1.4 m wide – all crashes						20		

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
	Bike lane adjacent to traffic (with or without marking) – all casualty crashes								15
	Bike lane adjacent to traffic (with or without marking) – all bicycle/vehicle casualty crashes								60
	Treatment life	20		5					

Given the significant variability of results in recent literature it was decided to maintain the existing values. It was also decided to redefine the treatment as ‘provide on-road bike lane’. The importance of considering exposure when planning a treatment of this type was also noted and reflected in the guidance notes for this treatment. Further, TMR noted that its preferred treatment for the safe movement of cyclists is a physically separated alternative (such as an off-road path).

C.4.23 ESTABLISHING A BICYCLE PATH OR SHARED PATH WHERE A BICYCLE LANE IS UNSUITABLE (E.G. TRAFFIC SWEEPING ACROSS TIGHT CORNER) OR CHILDREN COULD BE EXPECTED TO RIDE (WITHIN 2 KM OF SCHOOLS) (PEDESTRIAN AND BICYCLE ONLY) (4.25)

By taking cyclists off the road, greater separation is provided between them and motorised traffic. NZTA notes in its CRF values that research on the topic is limited and that the benefits of being separated from through traffic may be constrained by an increase in conflicts at access points and intersections. It has designated a 0% CRF for this treatment.

A single recent international study (Alluri et al. 2017) was identified on the use of a shared path and reported a 25% reduction in all crashes (including PDO) for shared paths on large divided roads. A summary of the CRFs is provided in Table C.183.

Table C.183: Summary of CRFs for establishing a bicycle path or shared path where a bicycle lane is unsuitable

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
2									
4	Rear end	20							
5	Lane change	20							
6	Parallel lanes turning	20							
7	Uturn	20							
8									
9	Overtaking, same direction	20							
10	Hit parked vehicle	20							
	Off-road bicycle path – all casualty crashes						0		
	Shared path – all crashes								25
	Treatment life	15							

The expert opinion of workshop attendees wase that the existing CRFs undersold the benefits of this treatment type, with physical separation of cycle facilities expected to significantly improve safety for cyclists. The revised CRFs are shown in Table C.184. It is noted that the CRFs are for midblock. Care needs to be taken with how the remaining conflict points – such as intersections and access points – are treated, as crashes may be concentrated at these locations and cyclist numbers encouraged through the improved safety (perceived or otherwise) midblock.   The treatment has also been redefined as ‘provide off-road bicycle or shared path’.

Table C.184: Changes to CRFs for establishing a bicycle path or shared path

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on			80	80
4	301 - 303	Rear end	20	20	80	80
5	305 - 307, 504	Lane change	20	20	80	80
6	308, 309	Parallel lanes turning	20	20	80	80
7	207, 304	U-turn	20	20	80	80
9	503, 505, 506	Overtaking, same direction	20	20	80	80
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	20	20	80	80
11	903	Hit railway train			80	80
13	605	Permanent obstruction			80	80
14	609, 905	Hit animal			80	80
15	502, 701, 702, 706, 707	Off carriageway on straight			80	80
16	703, 704, 904	Off carriageway on straight, hit object			80	80
17	705	Out of control, on straight			80	80
18	801, 802	Off carriageway, on curve			80	80
19	803, 804	Off carriageway on curve hit object			80	80
20	805 - 807	Out of control, on curve			80	80
21		Other			80	80
Treatment life			15		20	

C.4.24 INSTALLATION OF BICYCLE LANES AT SIGNALISED INTERSECTIONS (BICYCLE AND MOTORCYCLE ONLY) (4.26)

Bicycle lanes at signalised intersections highlight the presence of cyclists and can grant them designated space for navigating the intersection.

TMR was the only jurisdiction that had CRFs specifically for this treatment, however generic bicycle lane CRFs from other jurisdictions are provided for reference. Recent literature was identified (Alluri et al. 2017), however the quality was noted to be low. A summary of the CRFs is provided in Table C.185.

Table C.185: Summary of CRFs for installation of bicycle lanes at signalised intersections

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10							
3	Opposing vehicles turning - right through	10							
4	Rear end	10							
5	Lane change	10							
6	Parallel lanes turning	10							
7	U-turn	10							
9	Overtaking, same direction	10							
	On-road bicycle path – bicycle crashes[1]			30					
	On-road bicycle path – green marking			25					

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
	Lanes < 1.4 m wide – all crashes 1						10		
	Lanes > 1.4 m wide – all crashes1						20		
	Advance cycle start box						35		
	Vehicle/bicycle, all crashes, signalised intersection								-25
	Vehicle/bicycle, FSI crashes, signalised intersection								-70
	Vehicle/bicycle, all crashes, stop-controlled intersection								-35
	Treatment life	5		5					

1: These are generic treatments and not specific to intersections.

It is noted that the recent research was rated low quality (2 stars, CMF Clearinghouse rating). However, the research points to an increase in bicycle-related crashes as a result of the introduction of bicycle lanes. It is noted that as this CRF is based on the baseline condition of ‘no bicycle lanes’ it is possible that the introduction of the lanes has resulted in a surge in cyclist activity, meaning the increase in crashes is as a result of an increase in exposure, rather than caused bythe infrastructure .

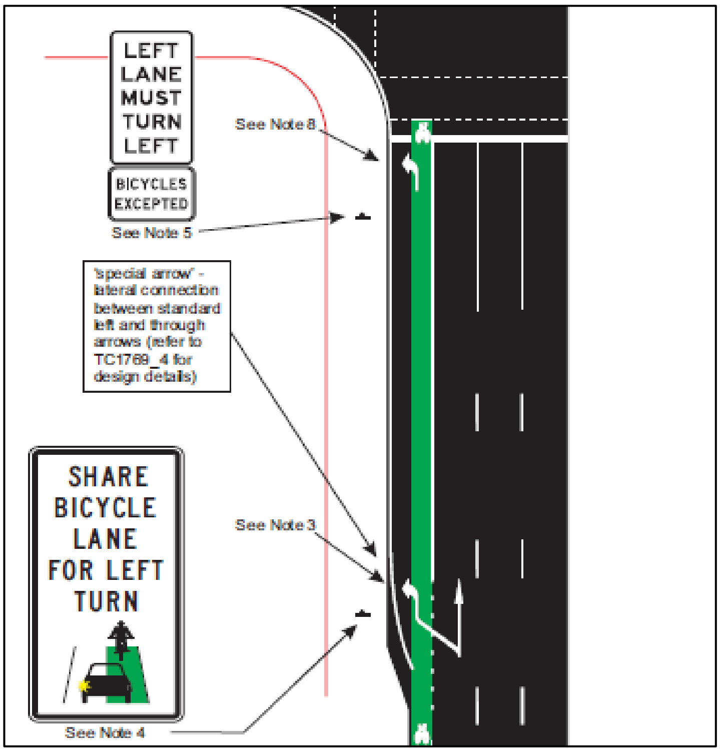
It should also be noted that motorcyclists are able to enter bicycle storage areas in Queensland. This rule differs across the jurisdictions and is not permissible in Victoria for example.

Given the low robustness of the research it was decided to maintain the existing bicycle CRFs.

C.4.25 TREATMENT OF AUXILIARY LEFT-TURN LANES WITH TC1769 WHERE APPLICABLE (BICYCLE ONLY) (4.27)

TC1769 relates to the marking of bicycle facilities in green paint within an auxiliary left-turn lane (Figure C.45). The treatment does not designate any additional space for cyclists and is instead designed to highlight their presence to drivers.

Figure C.45: Auxiliary left-turn lanes with TC1769



Source: Queensland Department of Transport and Main Roads (2013).

No other jurisdiction had this treatment in its CRF matrix and no recent literature was identified. It is noted however that this treatment is considered to be broadly similar to the previous treatment. A summary of the existing CRFs is provided in Table C.186.

Table C.186: Summary of CRFs for treatment of auxiliary left-turn lanes with TC1769

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches	10							
4	Rear end	10							
5	Lane change	10							
9	Overtaking, same direction	10							
	Treatment life	5							

Given the lack of literature on this topic it was decided to maintain the existing CRFs, however the treatment life was revised up to 10 years (from 5) in line with expert opinion.

C.4.26 ENHANCEMENT OF EXISTING BICYCLE LANES TO REDUCE VEHICULAR ENCROACHMENT/CONFLICT PARTICULARLY WHERE THERE IS EVIDENCE OF MOTOR VEHICLES SWEEPING THROUGH THE BICYCLE LANE. POSSIBLE TREATMENTS INCLUDE ATLM, GREEN SURFACE TREATMENT, PAINTED CHEVRON BUFFER OR SPLITTER KERB (BICYCLE ONLY) (4.28)

This treatment consists of a variety of different measures aimed at separating cyclists from the general traffic stream. However, it is expected that their operation will vary significantly. Green surface treatment for instance only provides drivers with a visual cue as to the presence of the bicycle lane, whereas a splitter kerb physically separates them from traffic.

Given the high degree of variability, it is expected that this will translate to a high degree of variability in performance in terms of crash reduction. A summary of the CRFs is provided in Table C.187. The recent literature relates to a report from the United States (Rothenberg et al. 2016).

Table C.187: Summary of CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
5	Lane change	20							
6	Parallel lanes turning	20							
9	Overtaking, same direction	20							
	On-road bicycle path – all casualty crashes[1]			25					
	Separated cycle paths alongside roads – one way for cyclists[2]						0		
	Install kerb separated bicycle lane – all vehicle/bicycle crashes								15
	Install green surface treatment separated bicycle lane – All vehicle/bicycle crashes								-65
	Install separated bicycle lane where a bicycle lane existed previously – all vehicle/bicycle crashes								-55
	Install kerb separated bicycle lane – all Crashes								30
	Install green surface treatment separated bicycle lane – All crashes								5
	Install separated bicycle lane where a bicycle lane existed previously – all crashes								10
	Treatment life	5		5					

1. *These are generic treatments from the baseline of 'no bicycle lane' as opposed to strictly enhancing existing bike lanes.*
2. *NZTA notes that there is limited information on these types of treatments and that the crash risk at intersections and minor road accesses may outweigh the midblock benefits.*

It is noted that the recent research was noted as being low quality (CMF Clearinghouse quality rating of 1 and 2 stars). As has been noted previously, exposure is a key element for cyclist crash risk that is not well understood. While several of these treatments are shown to have negative CRFs, it could be because the new infrastructure has concentrated cyclists at the location from other parallel routes or encouraged new cyclists, and crashes have increased simply as a result of there being more cyclists at the location.

Given this , and the lack of robust research generally, it was decided to maintain the existing CRFs, however the treatment life was increased to 10 years based on the expert opinion from workshop attendees.

C.4.27 TREATMENTS TO ENHANCE BICYCLE SAFETY AT ROUNDABOUTS (E.G. TREATMENTS TO EQUALISE MOTOR VEHICLE AND BICYCLE SPEED, INCREASE DRIVER ALERTNESS AND ENHANCE BICYCLE SEPARATION FROM TRAFFIC) (ROUNDABOUT ONLY) (4.29)

This treatment is also not well defined. These types of treatments may include converting from multi-lane to single-lane roundabouts, providing 'Dutch-style' roundabouts (separate cycle path running parallel to the traffic lane around the roundabout's circumference) or simply increased signage warning drivers of the presence of cyclists. An example of a bicycle safety treatment is shown in Figure C.46.

No other jurisdictions reported on this CRF and no recent literature was identified. A summary of the CRFs is provided in Table C.188.

Figure C.46: Enhanced bicycle safety treatment at a roundabout

Source: Vicroads as shown in Austroads (2015b).

Table C.188: Summary of CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches - cross-traffic	10							
4	Rear end	10							
5	Lane change	10							
6	Parallel lanes turning	10							
8	Entering roadway	10							
9	Overtaking, same direction	10							
	Treatment life	5							

Given the lack of research on this treatment it was decided to maintain the existing CRFs . The treatment life was increased from 5 to 20 years based on the expert opinion of workshop attendees.

The workshop attendees also highlighted the need to cross-reference further guidance on this treatment, specifically Department of Transport and Main Roads (2015), which details what sort of treatments this CRF relates to.

C.4.28 INSTALLATION OF BAZ WARNING MARKINGS IF APPROPRIATE, REFER TO TRUM 1.39 (BICYCLE ONLY) (4.30)

Bicycle advisory zones (BAZ) are advisory treatments, similar to warning signs. BAZ are used to indicate or ‘advise’ road users of the potential presence of cyclists and the position where cyclists may be expected to ride on the road.

None of the other jurisdictions recorded CRFs for this treatment, nor was any recent literature on the topic identified. A summary of the CRFs is provided in Table C.189.

Table C.189: Summary of CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches - cross-traffic	5							
3	Opposing vehicles turning	5							
4	Rear end	5							
8	Entering roadway	5							
9	Overtaking, same direction	5							
	Treatment life	5							

Given the lack of research or use in other jurisdictions no change to the existing CRFs for this treatment was proposed.

C.4.29 INSTALL PEDESTRIAN REFUGE, NO CROSSING MARKED (PEDESTRIAN AND BICYCLE ONLY) (4.31)

A refuge allows vulnerable road users to stage their crossing movement, providing a sheltered location where they can wait before continuing to cross the road (Figure C.47).

Several jurisdictions have CRFs for pedestrian refuges. It is noted that WA has a CRF of 40% for a raised median featuring a pedestrian refuge (pedestrian crashes), which is expected to operate broadly similarly from a pedestrian standpoint.

Makwasha et al. (2016) reported a 50% reduction in pedestrian crashes as a result of the introduction of pedestrian refuges and a 67% reduction in pedestrian fatalities. Makwasha etal. (2017) indicates a CRF of 40% for pedestrian FSI crashes. Recent literature was identified for 'raised medians with or without marked crosswalk' which is expected to operate broadly similarly with respect to pedestrian crashes and so is provided for information. A summary of the CRFs is provided in Table C.190.

Figure C.47: Pedestrian refuge, no marked crossing

Source: Makwasha et al. (2017).

Table C.190: Summary of CRFs for install pedestrian refuge, no crossing marked

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	TAC Report	Recent literature
1	Intersection, adjacent approaches - cross-traffic	20							
2	Head on	10 (L)	20 (L)						

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	TAC Report	Recent literature
8									
9	Overtaking, same direction		30 (L)						
10	Hit parked vehicle	50							
12	Hit pedestrian	20	10 (L)						
	Pedestrian casualty crashes							50	
	Pedestrian fatality crashes							65	
	All pedestrian/vehicle crashes								30
	Treatment life	15							

The ‘hit pedestrian’ CRF was realigned to more closely reflect the TAC report. Several other CRFs were adjusted in line with expert opinion, including introducing an ‘entering roadway’ CRF (Table C.191).

Table C.191: Changes to CRFs for install pedestrian refuge, no crossing marked

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	20	20	20	20
2	201, 501	Head on	10		10	10
8	401, 406 - 408	Entering roadway			40	40
10	402, 404, 601, 602, 604, 608	Hit parked vehicle	50	50		
12	001 - 009	Hit pedestrian	20	20	40	40
Treatment life			15		15	

C.4.30 ESTABLISH ADDITIONAL SIGNALISED CROSSINGS AT INTERSECTIONS LACKING CROSSINGS ON ALL LEGS (PEDESTRIAN AND BICYCLE ONLY) (4.32)

This treatment involves installing additional pedestrian crossings on legs at signalised intersections that were previously lacking a crossing facility. This helps to improve pedestrian desire lines at an intersection and potentially reduces the number of crossings a pedestrian is required to undertake.

No other jurisdictions identified a CRF for this treatment,nor was any recent literature identified.

It is noted that the TAC report (Makwasha et al. 2017) identifies CRFs for pedestrians signals at intersections generally, and not specifically for signals across a single leg. These CRFs are provided for reference, noting that they may be adequate estimates if only applied to crashes occurring on the targeted leg. A summary of the CRFs is provided in Table C.192.

Table C.192: Summary of CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	TAC report	Recent literature
12	Hit pedestrian	20	30 (L,M)[1,2]						
	Pedestrian signals at intersections – all casualty crashes							25	
	Pedestrian signals at intersections – all pedestrian casualty crashes							30	
	Pedestrian signals at intersections – all pedestrian FSI crashes							40	
	Treatment life	15							

1: The NSW treatment relates to the introduction of a pedestrian signal phase as opposed to an additional pedestrian crossing on a previously uncovered leg.

2: NSW definitions: L = low speed (<= 60 km/h) M = medium speed (70-80 km/h) and H = high speed (>= 90 km/h).

The outcome of the workshop was to revise the CRFs upwards in accordance with the TAC report noting the potential limitations of this CRF due to the difference in treatment type. The treatment life was also revised upwards based on expert opinion. The changes are shown in Table C.193.

Table C.193: Changes to CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
12	001 - 009	Hit pedestrian	20	20	40	40
	Treatment life		15		20	

C.4.31 CONVERTING STAGED CROSSINGS TO A SINGLE-PHASE CROSSING WHERE POSSIBLE (PEDESTRIAN AND BICYCLE ONLY)

This treatment involves replacing a staged crossing – where users are required to wait in the middle of the road – with a single crossing. This reduces the time pedestrians are exposed to traffic.

No other jurisdictions provided a CRF for this treatment and no recent literature was identified. A summary of the CRFs is provided in Table C.194.

Table C.194: Summary of CRFs for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
12	Hit pedestrian	20							
	Treatment life	15							

The outcome of the workshop was to revise the CRF upwards, based on expert opinion. This is shown in Table C.195.

Table C.195: Changes to CRF for enhancement of existing bicycle lanes to reduce vehicular encroachment/conflict

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
12	001 - 009	Hit pedestrian	20	20	40	40
	Treatment life		15		20	

C.4.32 FENCE NARROW-WIDTH FOOTPATHS ON BRIDGES WHERE PATH USERS MIGHT FALL DIRECTLY INTO A TRAFFIC LANE (PEDESTRIAN AND BICYCLE ONLY) (4.34)

Guardrails or fencing can help to direct the flow of pedestrians and prevent cyclists or pedestrians falling into a trafficked lane, especially in locations where width is restricted and volumes of vulnerable road users are high. An example of typical pedestrian fencing is shown in Figure C.48.

It is noted that while NSW, NZTA and Victoria have pedestrian-fence CRFs, they do not relate specifically to use on bridges. The TAC report also identifies the use of pedestrian fencing or guardrail to restrict access to the carriageway, or to direct pedestrians to dedicated crossing points but does not provide a CRF specifically for application on bridges. A summary of the CRFs is provided in Table C.196.

Figure C.48: Pedestrian fencing

Source: Austroads (n.d.)

Table C.196: Summary of CRFs for fencing of narrow footpaths on bridges

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	TAC	Recent literature
12	Hit pedestrian	50							
	Install pedestrian fencing on kerb		35 (L)						
	Pedestrian fences and barriers – pedestrian crashes			23					
	Install fencing and barriers to direct pedestrians – all casualty crashes						20	25	
	Pedestrian channelisation – Pedestrian casualties							30	
	Pedestrian channelisation – Pedestrian FSIs							40	
	Treatment life	10		20					

Given the lack of specific literature, it was decided to maintain the existing CRF values.

C.4.33 FENCE MEDIAN WHERE CRASHES HAVE OCCURRED AND CROSSING SIGHT DISTANCE IS NOT ACHIEVED (PEDESTRIAN ONLY AND ONLY AFTER ALL COMPLIANT CROSSING OPPORTUNITIES PROVIDED) (4.35)

Fencing a median – either with direct pedestrian fencing or with guardrail – helps to deter pedestrians from crossing at inappropriate locations, such as where sight distance is restricted (Figure C.49).

Several jurisdictions provide more generic pedestrian fencing treatments, and these are detailed in Table C.197 . The TAC report also details a number of pedestrian fencing CRFs. No other recent literature was identified.

Figure C.49: Pedestrian fencing in the median

Source: Makwasha et al.(2017).

Table C.197: Summary of CRFs for pedestrian fencing in median

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	TAC	Recent literature
12	Hit pedestrian	50							
	Install pedestrian fencing on median		45 (L)						
	Pedestrian fences and barriers – pedestrian crashes			23					
	Install fencing and barriers to direct pedestrians – all casualty crashes						20	25	
	Pedestrian channelisation – pedestrian casualties							30	
	Pedestrian channelisation – pedestrian FSIs							40	
	Treatment life	10		20					

Based on the expert opinion of workshop attendees, and the higher CRFs recorded for a similar treatment in the TAC report, it was decided to revise the CRFs for this treatment (Table C.198).

Table C.198: Changes to CRFs for pedestrian fencing in median

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
12	001 - 009	Hit pedestrian	50	50	25	25
Treatment life			10		10	

C.4.34 RETROFIT OF PEDESTRIAN FACILITIES WHERE WHEELCHAIRS OR MOBILITY SCOOTERS HAVE BEEN KNOWN TO BECOME STUCK ON KERB RAMPS (PEDESTRIAN ONLY)

Kerb ramps – sometimes referred to as pram crossings – provide access for prams, wheelchairs and the like. Potential hazards arise if inappropriate grades are used or the ramp is not flush with the carriageway creating a lip that could obstruct wheels.

None of the other jurisdictions reported on this issue and no recent literature was identified. A summary of the CRFs is provided in Table C.199.

Table C.199: Summary of CRFs for retrofitting of pedestrian facilities where wheelchairs or mobility scooters have been known to become stuck on kerb ramps (pedestrian only)

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
12	Hit pedestrian	50							

Crash type (DCA group)		TMR	NSW	VIC	WA	SA	NZTA	Austroads	Recent literature
	Treatment life	20							

Given the specificity of the treatment, it is unlikely it would be works to rectify this kind of defect would be done as a road safety project but should simply be done as a matter of course. The CRFs have therefore been removed from the matrix and alternative guidance provided.

C.4.35 ADDITIONAL TREATMENTS

The TAC report (Makwasha et al. 2017) outlines a number of additional treatments not currently contained in the matrix. These were considered, but ultimately it was decided not to include them in the matrix. They are outlined in Table C.200 for reference.

Table C.200: Additional treatments considered

Treatment type	Crash type	CRF (%)	Reliability	CRF from other jurisdictions (where applicable)				
				NSW	VIC	WA	SA	NZ
Intersection treatments								
Dwell-on-red traffic signals	Pedestrian crashes – casualty	50	Low		**50 (during operation)**			
	All crash types – casualty	45	*None indicated*		**47**	**45**		**50**
Countdown timer at signals	All crash types – casualty	45	*None indicated*					
Barnes Dance (stopping traffic and allowing diagonal pedestrian flow)	Pedestrian crashes – casualty	50	Low	**30**				
	All crash types – casualty	-			**55**			
Signalised raised intersection/safety platform	All crash types – casualty	40	*None indicated*		**20**	**30-60**	**50-60% if signalising and installing platform 30% at already signalised**	**20**
Improving pedestrian signal phasing	Pedestrian crashes – casualty	40	Medium					
	All crash types – casualty	45	*None indicated*		**10**			
	All crash types – FSI	35	*None indicated*					
High-visibility intersection crossing	Pedestrian crashes – casualty	80	Medium		**44**			
	All crash types – casualty	30	*None indicated*					
	All crash types – FSI	15	*None indicated*					
Midblock treatments								

Treatment type	Crash type	CRF (%)	Reliability	CRF from other jurisdictions (where applicable)				
				NSW	VIC	WA	SA	NZ
School crossing	Pedestrian crashes – FSI	80	Low					
Route or area-wide								
Convert angle parking to parallel parking	Pedestrian crashes – FSI	0	Low					
	All crash types – casualty	40	*None indicated*		**40**			
	All crash types – FSI	15	*None indicated*					
Footpath and/or shoulder provision	Pedestrian crashes – FSI	90	Medium					
	Pedestrian crashes – casualty		*None indicated*		**88 (walking along)**			
	All Crash types – casualty	40	*None indicated*					
Shared zone	Pedestrian crashes – FSI	80	Medium					
	All crash types – casualty	50	*None indicated*					

Note: The TAC report had a pedestrian focus and the reliability around all crash type CRFs was not provided.

Source: Based on Makwasha et al. (2017) and jurisdiction CRF tables.

C.5 TREATMENTS FOR RUN-OFF-ROAD CRASHES

C.5.1 INSTALL AUDIO-TACTILE LINE MARKING (ATLM) (EDGE) WITH SHOULDER WIDTH ≥ 1 M (5.01)

As the name implies, the treatment provides and audible and tactile warning to drivers that they are straying from their path. Consideration should be given to any noise-sensitive land uses adjacent to the road when implementing ATLM.

Austroads (2012) noted that edge lines with ATLM should be considered where there is a recorded history of fatigue-related crashes and may be considered on roads prone to fog.

The only recent literature specifically for this type of treatment reported a 16% reduction in run-off-road (to the left) crashes as shown in Table C.201. TMR indicated a 10% increase in off-carriageway crashes. A summary of CRFs identified are outlined in Table C.202.

Table C.201: CRFs from recent literature for installing ATLM on edge with shoulder width ≥ 1 m

Reference	Run-off-road	Notes
Savolainen et al. (2017)	16.1 (4 stars)	Edge-line-related crashes (run-off-road crashes without crossing the centreline), all crash severity
Weighted average	15	

Table C.202: Summary of CRFs for installing ATLM on edge with shoulder width ≥ 1 m (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS[2]	WA	VicRoads	NZTA	SA	Austroads[1]	Recent literature
1	Head-on		5	10	20					
2	Off carriageway on straight	to left	-10(L), 15(H)	25	20		30	30	40 (2012)	15
		to right	-10 (L), 15 (H)	5	20		30	30	40 (2012)	15
3	Off carriageway on straight, hit object	to left	-10 (L), 15(H)	25	20		30	30	40 (2012)	15
		to right	-10 (L), 15(H)	5	20		30	30	40 (2012)	15
4	Off carriageway, on curve		-10 (L), 15(H)	20	20		30	30	40 (2012)	15
5	Off carriageway on curve, hit object		-10 (L), 15(H)	20	20		30	30	40 (2012)	15
7	Out of control, on straight		5	10	20		30	30		
8	Out of control, on curve		10	10	20		30	30		
	All casualty					23			23 (2010) * 20 (2012)	
	Treatment life (years)		**5**			**5**				

1. *Austroads (2010) and (2012) both rated the CRFs as low/medium confidence.*
2. *NSW as the only source to denote different CRFs for left and right ROR crashes.*

In the workshop discussion it was highlighted that the previous increase in crash rates for 'off carriageway' crash types provided in the existing matrix was an error. Based on the Austroads literature and a number of other jurisdictions having higher crash reductions than the current values in the TMR matrix, the values were revised upwards. The changes to the matrix are outlined in Table C.203 .

Table C.203: Summary of changes to CRFs for installing ATLM on edge with shoulder width ≥ 1 m (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	5	5	5	5
15	502, 701, 702, 706, 707	Off carriageway on straight	-10	15	25	25
16	703, 704, 904	Off carriageway on straight, hit object	-10	15	25	25
17	705	Out of control, on straight	5	5	10	10
18	801, 802	Off carriageway, on curve	-10	15	25	25
19	803, 804	Off carriageway on curve hit object	-10	15	25	25
20	805 - 807	Out of control, on curve	10	10	10	10

C.5.2 INSTALL EDGE-LINE MARKING (RURAL ROAD) (5.02)

Installing edge lines (Figure C.52) helps provide drivers with a continuous guide by delineating the edges of sealed roads, thus making driving safer and more comfortable, particularly at night and under adverse weather conditions where visibility is impeded (Austroads 2012).

The CRFs sourced from recent literature are shown in Table C.204. A summary of CRFs from jurisdictions is outlined in Table C.205.

Figure C.50: Edge line and sealed shoulder

Source: Austroads (n.d.).

Table C.204: CRFs from recent international literature for installing edge-line marking on rural roads

Reference	All crashes	Notes
Sun et al. (2014)	15 (3 star)	Two-lane, undivided, rural, all crash severity
Sun and Das (2011)	22 (2 star)	Two-lane, undivided, rural, all crash severity
Weighted average	20	

Table C.205: Summary of CRFs for installing edge-line marking on rural roads (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on		-	10	15					
2	Off carriageway on straight	to left	15	25	15			30		
		to right	15	5				30		
3	Off carriageway on straight, hit object	to left	15	25	15			30		
		to right	15	5				30		
4	Off carriageway, on curve		15	20	15			30		
5	Off carriageway on curve, hit object		15	20	15			30		
7	Out of control, on straight		-	10	15			30		
8	Out of control, on curve		5	10	15			30		
	All crashes		-							20
	All casualty		-			10			10	
	Treatment life (years)		**5**			**5**		**5**		

In light of South Australia, NSW and recent literature indicating higher values, the CRFs for this treatment were revised upwards, and a CRF introduced for head-on crashes. It was decided not to distinguish between ROR (run-off-road) to the left and ROR to the right crashes as was done in NSW.

The revised values are outlined in Table C.206.

Table C.206: Summary of changes to CRFs for installing edge-line marking on rural roads (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on			10	10

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	15	15	20	20
16	703, 704, 904	Off carriageway on straight, hit object	15	15	20	20
17	705	Out of control, on straight			20	20
18	801, 802	Off carriageway, on curve	15	15	20	20
19	803, 804	Off carriageway on curve hit object	15	15	20	20
20	805 - 807	Out of control, on curve	5	5	20	20

C.5.3 INSTALL RRPMS ON CENTRE AND EDGE LINES (NIGHT-TIME CRASHES ONLY) (5.03)

Austroads (2012) indicated that installing raised reflective pavement markers (RRPMs) improves road delineation, particularly at night and in wet weather. RRPMs also provide tactile and audible warnings to drivers, similar to ATLM, when vehicles traverse the markers. They are typically used to supplement the dividing lines, lane lines and edge lines of two-lane rural roads and multi-lane freeways. RRPMs can be either one-way or two-way markers (i.e. reflective for only one direction of approaching traffic, or reflective for both directions). Isolated or continuous applications can be considered depending on the situation.

RRPMs (Figure C.53) can provide the following benefits:

- clear delineation of changes in alignment
- effective delineation of curves
- reduced need for the use of high-beam headlights, thereby reducing glare for oncoming motorists
- additional tactile and audible warning of lane departure
- improved delineation in wet weather and at night.

Figure C.51: RRPMs on centre and edge lines

Source: Austroads (2012).

CRFs identified from recent literature are outlined at Table C.207. It is noted that the literature only specified RRPMs generally and did not distinguish where or how they were implemented (lane line vs edge line, straight vs curve etc.). A summary of all CRFs identified is presented at Table C.208.

Table C.207: CRFs from recent international literature for installing raised reflective pavement markers

Reference	Night-time crashes	Notes
Sun and Das (2013)	19 (2 stars)	Principal arterial, other freeways and expressways, all crash severity, night-time, rural
	21 (2 stars)	
	14 (2 stars)	
Weighted average	20	

Table C.208: Summary of CRFs for installing RRPMs on centre and edge lines (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on		20	15	5					
2	Overtaking, same direction		5	5						
4	Off carriageway on straight	to left	20 (L), 25(H)	15	5					
5		to right	20 (L), 25(H)	15	5					
6	Off carriageway on straight - hit object	to left	20 (L), 25(H)	15	5					
7		to right	20 (L), 25(H)	15	5					
8	Out of control, on straight		-	15						
9	Off carriageway, on curve,	to left	20(L), 40(H)	15	5					
10		to right	20(L), 40(H)	15	5					
11	Off carriageway on curve, hit object,	to left	20(L), 40(H)	15	5					
12		to right	20(L), 40(H)	15	5					
13	Out of control, on curve		20	15						
	All crashes									20
	All casualty crashes					5	5[1]		5 (2012)	
	Treatment life (years)		**5**			**10**		**5**		

1. *The NZTA CRF relates to the use of RRPMs on the centreline.*

Based on the literature and values used in other jurisdictions, the existing 25% and 40% CRFs for high-speed crashes were considered to be too high, and were revised down to 20% with no differentiation between speed classes. The revised CRFs are outlined in Table C.209.

Table C.209: Summary of changes to CRFs for installing RRPMs on centre and edge lines (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	20	20	20	20
9	503, 505, 506	Overtaking, same direction	5	5	5	5
15	502, 701, 702, 706, 707	Off carriageway on straight	20	25	20	20
16	703, 704, 904	Off carriageway on straight, hit object	20	25	20	20
18	801, 802	Off carriageway, on curve	20	40	20	20
19	803, 804	Off carriageway on curve hit object	20	40	20	20
20	805 - 807	Out of control, on curve	20	20	20	20

C.5.4 INSTALL RRPMS ON EDGE LINES (NIGHT-TIME CRASHES ONLY) (5.04)

Installing RRPMs on edge lines enhances the reflectivity of the lines and hence provides drivers with better visibility .

No CRFs were sourced from recent literature and a summary of CRFs from jurisdictions is provided in Table C.210.

Table C.210: Summary of CRFs for installing RRPMs on edge lines (night-time crashes only) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	5	15						
2	Overtaking, same direction	-	5						
3	Overtaking, turning	-	5						
4	Off carriageway on straight	5(L), 10(H)	15						
5	Off carriageway on straight - hit object	5(L), 10(H)	15						
6	Out of control, on straight	-	15						
7	Off carriageway, on curve	5(L), 10(H)	15						
8	Off carriageway on curve, hit object	5(L), 10(H)	15						
9	Out of control, on curve	15	15						
	All casualty, head-on, run-off-road, night-time	-		5				5 (2010 & 2012)	
	Treatment life (years)	**5**			**10**				

** Only specified CRFs for installing RRPMs without indicating the locations (i.e. edge line and centreline).*

The TMR default policy position is to install both edge line and centreline RRPMs. While RRPMs in isolation may be considered on a case-by-case basis, it was decided not to include a CRF within the matrix.

C.5.5 CHANGE HORIZONTAL ALIGNMENT (5.05)

Changing horizontal alignment is a high-cost treatment for improving safety , usually involving reconstruction of entire sections of the carriageway. Road re-alignment can involve increasing the curve radius and generally leads to improved sight distance and safety . Realignment of the approach to an intersection may also be applied to change the approach speed and to reinforce the intersection priority (Austroads 2012).

The CRFs sourced from recent literature are provided in Table C.211. A summary of CRFs specified by jurisdictions and from the literature is provided in Table C.212.

Table C.211: CRFs from recent literature for changing horizontal alignment (% reduction)

Reference	Run-off-road*	All injuries	All crashes
Srinivasen et al. (2018)	78.4 (4 stars)	74.1 (5 stars)	68.5 (5 stars)
Weighted average	80	75	70

**The CRF for run-off-road crashes is for all crash severity.*

Table C.212: Summary of CRFs for changing horizontal alignment (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS*	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	20 (L),40(H)	20 (M), 40(H)						
2	Off carriageway, on curve	20 (L), 70(H)	50(M), 70 (H)		40				80
3	Off carriageway on curve, hit object	20 (L), 70(H)	50M), 70 (H)		40				80
4	Out of control, on curve	20	50(M), 70 (H)						

No.	Crash type (DCA group)	TMR	NSW RMS*	WA	VicRoads	NZTA	SA	Austroads	Recent literature
	All crashes								70
	All casualty								75
	Treatment life (years)	**20**			**25**				

**The RMS values refer to a change in horizontal radius from < 200 m to 600 m-1000 m at medium (70-80 km/h) and high (90 km/h+) speeds.*

It was noted in the workshop that this treatment was heavily reliant on baseline conditions as well as the ultimate alignment of the road, with significant changes to alignment having greater impacts on the potential CRFs than smaller changes. To this end, this treatment has been updated to refer to the operating speed model as outlined in Queensland Department of Transport and Main Roads (2017). It should be noted that this treatment and the associated CRFs apply only to substantial changes in alignment.

Table C.213: Summary of changes to CRFs for changing horizontal alignment (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	20	40	50	50
18	801, 802	Off carriageway, on curve	20	70	80	80
19	803, 804	Off carriageway on curve hit object	20	70	80	80
20	805 - 807	Out of control, on curve	20	20	80	80

C.5.6 PROVIDE ACCEPTABLE SUPERELEVATION (5.06)

Austroads (2015a) indicates that a lack of sufficient pavement superelevation at horizontal curves could result in loss-of-control crashes where side friction is insufficient to counteract centrifugal forces. Providing superelevation supports the inward centripetal forces needed to maintain a circular path. The amount of superelevation needed depends on the factors such as curve radius and design speed.

No updated CRFs were sourced from recent literature for providing acceptable superelevation. Table C.214 shows the summary of the CRFs provided by jurisdictions.

Table C.214: Summary of CRFs for providing acceptable superelevation (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	25 (L), 50(H)	25 (L), 50(H)				50		
2	Off carriageway, on curve	25 (L), 50(H)	25 (L), 50(H)				80		
3	Off carriageway on curve, hit object	25 (L), 50(H)	25 (L), 50(H)				80		
4	Out of control, on curve	25	25 (L), 50(H)				80		
	All casualty	-			20				
	Treatment life (years)	**20**			**25**				

Discussions at the workshop noted that this treatment is not commonly used or supported by TMR and as such it has been removed from the matrix.

C.5.7 REST-AREA PROVISION (5.07)

ARRB Transport Research (2005) noted that the operators of commercial vehicles drive for long distances over the period of time when they should be naturally sleeping. Providing rest areas can improve safety by allowing drivers to take short naps and thereby reduce the number of crashes related to fatigue. A general rule provided in ARRB Transport Research (2005) is as follows:

- Major rest areas should be located at maximum intervals of 100 km.
- Minor rest areas should be located at maximum intervals of 50 km.
- Truck parking bays should be located at maximum intervals of 30 km.

Table C.215 shows the CRFs sourced from recent literature. Only TMR specified CRFs for this particular treatment as shown in Table C.216.

Table C.215: Rest-area provision CRFs from recent literature (% reduction)

Reference	All crashes	Fatigue-related crashes
Sharif et al. (2014)	23 (2 stars)	-
	18 (2 stars)	-
Jung et al. (2017)	-	27 (3 stars)
Weighted average	20	25

Table C.216: Summary of CRFs for providing rest areas (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	5							
2	Off carriageway, on straight	5							
3	Off carriageway on straight - hit object	5							
4	Out of control, on straight	5							
5	Off carriageway, on curve	5							
6	Off carriageway on curve, hit object	5							
7	Out of control, on curve	5							
	All crashes								20
	Fatigue crashes								25
	Treatment life (years)	**20**							

TMR specifies its own guidance on the use of rest areas, with a standard spacing of 80 km. Further details are provided in *Rest Areas and Stopping Places – Location, Design and Facilities* (Queensland Department of Transport and Main Roads 2014). Given the higher CRFs values reported in recent literature, it was seen as appropriate to increase the CRFs for this treatment type as shown in Table C.217.

Table C.217: Summary of changes to CRFs for providing rest areas (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	5	5	25	25
15	502, 701, 702, 706, 707	Off carriageway on straight	5	5	25	25
16	703, 704, 904	Off carriageway on straight, hit object	5	5	25	25
17	705	Out of control, on straight	5	5	25	25
18	801, 802	Off carriageway, on curve	5	5	25	25
19	803, 804	Off carriageway on curve hit object	5	5	25	25
20	805 - 807	Out of control, on curve	5	5	25	25

C.5.8 INSTALL SHOULDER FROM ‘NO SHOULDER OR UNSEALED’ TO > 1 M SEALED (5.08)

Austroads (2012) noted that a sealed shoulder (Figure C.52) allows for vehicles to safely recover from the shoulder area back onto traffic lanes. The chances of stopping and recovery will increase if the shoulder width and skid resistance are sufficient. The benefits for sealing shoulders are as follows:

- Widening/sealing can structurally support the existing roadway pavement.
- Sealing prevents water from ponding in the main carriage pavement.
- Sealing works may provide an opportunity to review and remove roadside hazards.
- Sealing decreases the probability of edge drops.

Figure C.52: Sealed shoulder

Source: Austroads (2012).

The CRFs sourced from recent literature are provided in Table C.218. A summary of CRF values provided by recent literature and jurisdictions is shown in Table C.219. Apart from TMR and NSW, all other jurisdictions and Austroads only provide CRFs for sealing a shoulder from an unsealed condition without specifying the exact width of the sealed section. Those CRFsfrom jurisdictions that do not indicate the sealed shoulder width are provided in all the sections related to providing new sealed shoulders (this section, Section C.5.9, Section C.5.10 and Section C.5.11).

Table C.218: Install shoulder from ‘no shoulder or unsealed’” to > 1 m sealed CRFs from recent literature (% reduction)

Reference	Fixed object, run-off-road, head-on, side swipe* - all injuries	Run-off-road and head-on* - all Casualty	All casualty crashes	All crashes	Notes
Zeng et al. (2013)		77 (3 stars)		42 (3 stars)	All crash severity, major collector, rural. The cross-sectional model compares narrow unpaved shoulders to wide unpaved shoulders.
			72 (3 stars)		Major collector, rural. The cross-sectional model compares narrow unpaved shoulders to wide unpaved shoulders.
Bamzai et al. (2011)	-2 (3 stars)				All injuries, multi-lane, 56-105 km/h.
	3 (3 stars)				All injuries, multi-lane, 56-105 km/h.
	67 (3 stars)				All injuries, two-lane, 56-105 km/h.
	21 (3 stars)				All injuries, two-lane, 56-105 km/h.
	14 (3 stars)				All injuries, multi-lane, shoulder width ≤ 2.4 m, 56-105 km/h.
	28 (3 stars)				All injuries, two-lane, shoulder width ≤ 2.4 m, 56-105 km/h.
	15 (3 stars)				All injuries, multi-lane, shoulder width ≤ 3.7 m, 56-105 km/h.
	64 (3 stars)				All injuries, two-lane, shoulder width ≤ 3.7 m, 56-105 km/h.
	2 (3 stars)				All injuries, two-lane, shoulder width ≥ 3.7 m, 56-105 km/h.
Weighted average	25	75	70	40	

** It is noted that there is a significant amount of variation in the results of the Bamzai et al. study. This appears to be caused by the variations in the types of sites being treated, and suggests that base conditions are a highly important consideration for this treatment type.*

Table C.219: Summary of CRFs for installing sealed shoulder width > 1 m from no sealed shoulder (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA**	VicRoads**	NZTA**	SA	Austroads**	Recent literature
1	Head-on		30	35	40					
2	Off carriageway, on straight	to left	45	45		30		40		
		to right	45	35						
3	Off carriageway on straight - hit object	to left	45	45		30		40		
		to right	45	35						
4	Out of control, on straight		45	40				40		
5	Off carriageway, on curve		45			30		40		
6	Out of control, on curve		45					40		
7	Off carriageway on curve, hit object		45			30		40		
8	All casualty						30*		30 (2010 & 2012)	70
9	FSI crashes					14				

No.	Crash type (DCA group)	TMR	NSW RMS	WA**	VicRoads**	NZTA**	SA	Austroads**	Recent literature
10	Fixed object, run-off-road, head-on, sideswipe*– all injuries								25
11	Run-off-road and head-on – all casualties								75
12	All crashes								40
	Treatment life (years)	**20**			**25**		**20**		

**The CRF provided by NZTA is based on typical shoulder widths of greater than 0.75 m.*

***General sealing of shoulders, as opposed to specific widths.*

Given the lower CRFs outlined in a number of sources, including Austroads literature, the outcome of the workshop was to reduce the current CRFs (Table C.220).

Table C.220: Summary of changes to CRFs for installing sealed shoulder width > 1 m from no sealed shoulder (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	30	30	20	20
15	502, 701, 702, 706, 707	Off carriageway on straight	45	45	35	35
16	703, 704, 904	Off carriageway on straight, hit object	45	45	35	35
17	705	Out of control, on straight	45	45	35	35
18	801, 802	Off carriageway, on curve	45	45	35	35
19	803, 804	Off carriageway on curve hit object	45	45	35	35
20	805 - 807	Out of control, on curve	45	45	35	35

C.5.9 INSTALL SHOULDER FROM ‘NO SHOULDER OR UNSEALED’ TO 0.5–1 M SEALED (5.09)

The CRFs sourced from recent literature are provided in Table C.221 and the complete list of CRFs can be found in Table C.222. The values vary significantly in the one study identified. Given this variability, the results are not considered reliable and an average was not calculated.

A summary of CRFs specified by jurisdictions is provided in Table C.222.

Table C.221: Install shoulder from ‘no shoulder or unsealed’ to 0.5–1 m sealed CRFs from recent literature (% reduction)

Reference	Run-off-road and head-on	All injuries	All crashes	Comments
Zeng and Schrock (2012)	33 (3 stars)	6 (3 stars)	-11 (4 stars)	Narrow and wide shoulders
	61 (3 stars)	31(3 stars)	14 (4 stars)	Upgrading narrow unpaved shoulders (≤ 1.5 m) to composite shoulders
Weighted average				

Table C.222: Summary of CRFs for installing 0.5 to 1 m sealed shoulder width from no sealed shoulder (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA**	VicRoads**	NZTA**	SA	Austroads**	Recent literature
2	Head-on		20	25	40					
15	Off carriageway, on straight	to left	30	35		30		40		
		to right	30	25						
16	Off carriageway on straight - hit object,	to left	30	35		30		40		
		to right	30	25						
17	Out of control, on straight		30	30				40		
18	Off carriageway, on curve		30			30		40		
19	Off carriageway on curve, hit object		30					40		
20	Out of control on curve		30			30		40		
8	All casualty						30*		30 (2010 & 2012)**	
9	FSI crashes					14				
	Treatment life (years)		**20**			**25**		**20**		

**The CRF provided by NZTA is based on typical shoulder widths of greater than 0.75 m.*

***General sealing of shoulders, as opposed to specific widths.*

The CRFs for this treatment were reduced, noting the values from the previous treatment (Table C.223).

Table C.223: Summary of changes to CRFs for installing 0.5 to 1 m sealed shoulder width from no sealed shoulder (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	20	20	15	15
15	502, 701, 702, 706, 707	Off carriageway on straight	30	30	25	25
16	703, 704, 904	Off carriageway on straight, hit object	30	30	25	25
17	705	Out of control, on straight	30	30	25	25
18	801, 802	Off carriageway, on curve	30	30	25	25
19	803, 804	Off carriageway on curve hit object	30	30	25	25
20	805 - 807	Out of control, on curve	30	30	25	25

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C.5.10 SEALED SHOULDER 1.0 METRE FROM THROUGH LANE (5.10)

This treatment is interpreted as widening an existing sealed shoulder to 1 m . One study was identified for widening a sealed shoulder to (approximately) 1 m (Table C.224). A summary of CRFs specified by jurisdictions is provided in Table C.225.

Table C.224: Widen shoulder to 1 m CRFs from recent literature (% reduction)

Reference	Crash type	Crash severity	CRF	Comments
Li et al. (2013)	Fixed object, head- on, run- off-road, sideswipe	Fatal	14 (3 stars)	Rural, principal aarterial iinterstate
			-2 (3 Stars)	Rural, not specified
			2 (3 Stars)	Urban, principal arterial interstate
			0 (3 Stars)	Urban, not specified
		All injury (excl. fatal)	-10 (3 Stars)	Rural, principal arterial interstate
			4 (3 Stars)	Rural, not specified
			1 (3 Stars)	Urban, principal arterial interstate
			2 (3 Stars)	Urban, not specified

Note: The actual treatment was an increase from 0 to 3 ft.

Table C.225: Summary of CRFs for sealed shoulder 1 m from through lane (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on		10	10						
2	Off carriageway, on straight	to left	20	15						
		to right	20	10						
3	Off carriageway on straight - hit object,	to left	20	15						
		to right	20	10						
4	Out of control, on straight		20	10						
5	Off carriageway, on curve		20							
6	Out of control, on curve		20							
7	Off carriageway on curve, hit object		20							
8	All casualty								30*	
9	FSI crashes					14				
	Treatment life (years)		**20**			**25**		**20**		

** Both Austroads (2010) and (2012) specified 30%.*

This treatment was seen to be generally comparable to previous treatments, noting 'Install Shoulder from 'no shoulder or unsealed' to > 1 m sealed (5.08)" in particular. As such it was decided to remove it from the matrix,

C.5.11 SEALED SHOULDER 2.0 M FROM THROUGH LANE (5.11)

This treatment is interpreted as widening an existing sealed shoulder to a 2 m sealed shoulder.

The CRFs sourced from recent literature have been provided in Table C.226. The weighted average of 20% has been applied to off-carriageway crashes, head-on crashes and the crashes involving hitting an object.

A summary of CRFs specified by jurisdictions is provided Table C.227.

Table C.226: CRFs for sealed shoulder 2m from through lane from international literature (% reduction)

Reference	Crash type	Crash severity	All crashes	Comments
Li et al. (2013)	Fixed object, head-on, run- off-road, sideswipe	Fatal	11 (3 Stars)	Rural, principal arterial interstate
			-2 (3 Stars)	Rural, not specified
			17 (3 Stars)	Urban, principal arterial interstate
			4 (3 Stars)	Urban, not specified
		All injury (excl. fatal)	-15 (3 Stars)	Rural, principal arterial interstate
			4 (3 Stars)	Rural, not specified
			5 (3 Stars)	Urban, principal arterial interstate
			4 (3 Stars)	Urban, not specified

Note: The actual treatment was an increase from 0 to 6 ft.

Table C.227: Summary of CRFs for sealed shoulder 2 m from through lane (% reduction)

No.	Crash type (DCA group)		TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on		20	10	40					20
2	Off carriageway, on straight	to left	35	15		30		40		20
3		to right	35	10						20
4	Off carriageway on straight - hit object,	to left	-	15		30		40		20
5		to right	-	10						20
6	Out of control, on straight		35	10				40		
7	Off carriageway, on curve		35			30		40		20
8	Out of control, on curve							40		
9	Off carriageway on curve, hit object		35			30		40		20
10	All casualty								30*	
11	FSI Crashes					14				
	Treatment life (years)		**20**			**25**		**20**		

** Both Austroads (2010) and (2012) specified 30%.*

This treatment was seen to be generally comparable to previous treatments, noting Install Shoulder from 'no shoulder or unsealed' to > 1 m sealed (5.08) in particular. As such it was decided to remove it from the matrix.

C.5.12 INSTALL TRAVERSABLE HEADWALL (CULVERT IMPACTS ONLY) (5.12)

This treatment can decrease the severity of run-off-road crashes.

No CRFs could be sourced from recent literature. A summary of CRFs specified by jurisdictions is provided in Table C.228. No other jurisdictions other than TMR have specified CRFs for this treatment.

Table C.228: Summary of CRFs for installing traversable headwall (culvert impacts only) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight - hit object	90							
2	Off carriageway on curve, hit object	90							
	Treatment life (years)	**20**							

While no research was identified, expert opinion of those in the workshop was that the current CRF values were overstated, and accordingly have been reduced (Table C.229).

Table C.229: Changes to CRFs for installing traversable headwall (culvert impacts only) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
16	703, 704, 904	Off carriageway on straight, hit object	90	90	50	50
19	803, 804	Off carriageway on curve hit object	90	90	50	50

C.5.13 WIDEN CLEAR ZONE (VARIOUS TREATMENTS)

Austroads (2012) noted that providing a clear zone can allow space for the driver of a vehicle that runs off the road to regain control while sustaining minimum damage to the vehicle and its occupants. A clear zone is defined to start at the outer edge of the trafficable lane that is available for safe use by errant vehicles. Widening a clear zone requires relocation or removal of nontraversable/nonfrangible objects located within it. This treatment is also particularly important near bends or intersections. The benefits for widening clear zones are as follows:

- reduction in the severity of run-off-road crashes
- higher potential for errant vehicle to regain control or stop safely
- reduction in roadside asset maintenance costs caused by damage.

Several variants on clear zones are provided throughout the existing CRF matrix, including the following treatments:

- Widen clear zone (add 6 m).
- Widen clear zone from 1 to 5 m.
- Widen clear zone (0–2 m) to (4–8 m).
- Widen clear zone (0–2 m) to (> 8 m).
- Widen clear zone from 5 to 9.1 m.
- Treatment of roadside hazards – removal
- Treatment of roadside hazards – set back

There is significant overlap between these treatments, and accordingly some rationalisation was considered appropriate. Austroads (2014) notes that the greatest benefits in widening of the clear zone occurs when widening from 0 to 4 m, with returns diminishing with increasing clear zone widths. As a result, generic 'widen clear zone' treatments that do not consider base conditions are not appropriate. It is also noted that 'removal of hazards' and 'set back hazard' treatments are effectively the same as widen clear zone treatments.

Austroads (2014) developed Crash Modification Factors (CMFs) for changes to clear zone widths. The CMFs are detailed in Table C.230 . It is noted that they are based on an undivided two-lane rural highway, and that wide confidence intervals were noted around each CMF, indicating low reliability.

Table C.230: CMFs by clear zone width

Clear zone (m)	Run-off-road to left	Run-off-road to right
0–2	2.79	1.57
2–4	1.78	1.56
4–8	1.21	1.03
> 8	1	1

Source: Austroads (2014).

Based on the above, the following treatments are proposed:

- Increase the distance to roadside hazards from 0–2 m to 2–4 m.
- Increase Distance to Roadside Hazards from 0–2m to 4–8m.
- Increase Distance to Roadside Hazards from 0–2m to >8m.

These revised treatments were discussed amongst stakeholders at the workshop and it was decided that these were to be adopted.

Increase Distance to Roadside Hazards from 0–2 m to 2–4 m

No other jurisdictions have a CRF for this treatment. A CRF has been calculated based on Austroads (2014)as shown in Table C.231. No other recent literature was identified.

Table C.231: Summary of CRFs for widening clear zone (0–2 m) to (2–4 m) (% reduction)

No.	Crash type (DCA group)	TMR[1]	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway, on straight	54							
2	Off carriageway on straight – hit object	54							
3	Off carriageway, on curve	54							
4	Off carriageway on curve, hit object	49							
5	Run-off-road to left							36	
6	Run-off-road to right							1	
	Treatment life (years)	**20**			**20**				

1. *Based on 'widen clear zone (0–2 m) to (4–8 m)' from the existing matrix, provided for comparison purposes only.*

As there are no existing CRFs for this treatment, the values adopted (Table C.232) are based on Austroads (2014) , noting that it was decided not to distinguish between left and right-hand-side crashes.

Table C.232: Summary of CRFs for widening clear zone (0–2) to (2–4) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight			25	25
16	703, 704, 904	Off carriageway on straight, hit object			25	25
18	801, 802	Off carriageway, on curve			25	25
19	803, 804	Off carriageway on curve hit object			25	25

Increase Distance to Roadside Hazards from 0–2 m to 4–8 m

No other jurisdictions have a CRF for this treatment. A CRF has been calculated based on Austroads (2014) as shown in Table C.233. No other recent literature was identified.

Table C.233: Summary of CRFs for widening clear zone (0–2) to (4–8) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway, on straight	54							
2	Off carriageway on straight – hit object	54							
3	Off carriageway, on curve	54							
4	Off carriageway on curve, hit object	49							
5	Run-off-road to left							57	
6	Run-off-road to right							34	
	Treatment life (years)	**20**			**20**				

Based on Austroads (2014) it was decided in the workshop to round down the existing values, slightly reducing the CRF.

The changes to the CRFs are provided in Table C.234.

Table C.234: Summary of changes to CRFs for widening clear zone (0–2) to (4–8) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	54	54	50	50
16	703, 704, 904	Off carriageway on straight, hit object	54	54	50	50
18	801, 802	Off carriageway, on curve	54	54	50	50
19	803, 804	Off carriageway on curve hit object	49	49	50	50

Increase Distance to Roadside Hazards from 0–2 m to > 8 m

No other jurisdictions have a CRF for this treatment. A CRF has been calculated based on Austroads (2014) as shown inTable C.235. No other recent literature was identified.

Table C.235: Summary of CRFs for widening clear zone (0–2) to > 8 m (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	WA	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway, on straight	54							
2	Off carriageway on straight – hit object	54							
3	Off carriageway, on curve	54							
4	Off carriageway on curve, hit object	49							
5	Run-off-road to left							64	
6	Run-off-road to right							36	
	Treatment life (years)	**20**			**20**				

Based on Austroads (2014) it was decided in the workshop to round down the existing values, slightly reducing the CRF.

A summary of the changes is in Table C.236 .

Table C.236: Summary of changes to CRFs for widening clear zone (0–2) to > 8 m (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	54	54	55	55
16	703, 704, 904	Off carriageway on straight, hit object	54	54	55	55
18	801, 802	Off carriageway, on curve	54	54	55	55
19	803, 804	Off carriageway on curve hit object	54	54	55	55

Step Changes

It is noted that the preceding clear zone treatments all relate to the base case of a 0–2 m clear zone. As CRFs are relative metrics, 'step changes' can be calculated by comparing the appropriate CRFs. For instance, a CRF for increasing the offset to roadside hazards from 2–4 m to > 8 m can be calculated by comparing the 0-2 m to 2-4 m CRF with the 0–2 to > 8 m CRF.

C.5.14 FLATTEN SLOPE 1:3 TO 1:4 (5.141)

This treatment requires the flattening of an embankment slope on the roadside from a gradient of 1:3 to 1:4.

There were no updated CRFs sourced from recent literature for the treatment , however a similar treatment from Austroads (2014) is provided for reference. A summary of CRFs specified by jurisdictions is provided in Table C.237. No jurisdictions other than TMR have CRFs for this treatment, however VicRoads has CRFs based on different slope modifications, including 6% for general 'side-slope flattening'.

Table C.237: Summary of CRFs for flattening slope 1:3 to 1:6 (% reduction)

No.	Crash type (DCA Group)	TMR[1]	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight	42						
2	Off carriageway on straight, hit object	42						
3	Off carriageway on curve	42						
4	Off carriageway on curve, hit object	42						
5	All casualty			6[2]				
6	Run-off-road to left flatten slope from 1:2-1:3.5 to 1:3.5 to 1;6						15	
7	Run-off-road to right flatten slope from 1:2-1:3.5 to 1:3.5 to 1;6						23	
	Treatment life (years)	**20**		**25**				

1. *The TMR values relate to the previous treatment; 1:3 to 1:4 change in slope.*
2. *VicRoads specified 6% as a general reduction factor for all slope modifications.*

It was noted in the workshop that a 1:4 slope is still considered to be a significant risk, particularly for rollovers. Accordingly, a treatment that still resulted in a sub-standard arrangement was not considered appropriate for inclusion in the CRFs.

Accordingly, this treatment was proposed to be revised to flatten the slope from 1:3 to 1:6. The revised treatment CRFs are shown in Table C.238.

Table C.238: Summary of changes to CRFs for flattening slope 1:3 to 1:6 (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight			20	20
16	703, 704, 904	Off carriageway on straight, hit object			20	20
18	801, 802	Off carriageway, on curve			20	20
19	803, 804	Off carriageway on curve hit object			20	20

C.5.15 FLATTEN SLOPE 1:4 TO 1:6 (5.142)

No updated CRFs were sourced from recent literature for flattening the slope from gradient 1:4 to 1:6, however a similar treatment from Austroads (2014) is provided for comparison. A summary of CRFs specified by jurisdictions is provided in Table C.239. VicRoads was the only other jurisdiction that had a CRF for this treatment.

Table C.239: Summary of CRFs for flattening slope 1:4 to 1:6 (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight	22						
2	Off carriageway on straight, hit object	22						
3	Off carriageway on curve	22						
4	Off carriageway on curve, hit object	22						
5	All casualty			7				
6	Run-off-road to left – flatten slope from 1:6-1:3.5 to < 1:6						40	
7	Run-off-road to right – flatten slope from 1:6-1:3.5 to < 1:6						29	
	Treatment life (years)	**20**		**25**				

The outcome from the workshop discussion was for this treatment to be revised down, noting the agreed values for the previous treatment and its expected relative performance (Table C.240).

Table C.240: Summary of changes to CRFs for flattening slope 1:4 to 1:6 (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	22	22	15	15
16	703, 704, 904	Off carriageway on straight, hit object	22	22	15	15
18	801, 802	Off carriageway, on curve	22	22	15	15
19	803, 804	Off carriageway on curve hit object	22	22	15	15

C.5.16 TREATMENT OF ROADSIDE HAZARDS – FRANGIBLE (SLIP BASE/IMPACT ABSORBENT) (5.17)

This treatment involves replacing non-frangible poles with frangible ones (slip base/impact absorbent). No CRFs were sourced from recent literature other than the Austroads (2014) report . A summary of CRF values from jurisdictions is provided in Table C.241. VicRoads specified 25% and 35% for replacing rigid with impact absorbent and slip-based poles respectively.

Table C.241: Summary of CRFs for installing frangible poles (slip base/impact absorbent) (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads[1]	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight							
2	Off carriageway on straight, hit object	80	60	25, 35			40	
3	Off carriageway on curve							
4	Off carriageway on curve, hit object	80	60	25, 35				
	Treatment life (years)	**15**						

1. VicRoads values represent impact absorbent and slip base poles respectively.

The outcome of the workshop discussion was that — with consideration of other jurisdictions and the Austroads work — the existing CRFs were overstated. Accordingly, they were reduced as shown in Table C.242.

Table C.242: Summary of changes to CRFs for installing frangible poles (slip base/impact absorbent) (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
16	703, 704, 904	Off carriageway on straight, hit object	80	80	40	40
19	803, 804	Off carriageway on curve hit object	80	80	40	40

C.5.17 FENCING OF STOCK (5.18)

No CRFs were sourced from recent literature for the fencing of stock. A summary of CRF values from jurisdictions is provided in Table C.243

Table C.243: Summary of CRFs for fencing of stock

Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
Hit animal	90	90					
Treatment life (years)	**10**						

No literature on this treatment was identified, however based on the workshop discussions it was decided to reduce the CRF slightly (Table C.244).

Table C.244: CRFs for fencing of stock

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
14	609, 905	Hit animal	90	90	80	80

C.5.18 INSTALL W-BEAM GUARDRAIL ON ROADSIDE FROM NO EXISTING BARRIER (5.19)

The iRAP (2010) specified w-beam guardrail also refers to semi-flexible barriers which are usually made from steel beams or rails. These types of barrier deform less during impact compared to flexible barriers, therefore they can be located closer to the hazard when space is limited. Semi-rigid barriers may be able to redirect secondary impacts depending on the impact. Properly designed barriers should reduce the severity of crashes related to out-of-control vehicles. An example of a w-beam barrier is shown in Figure C.53.

The CRFs sourced from recent literature are provided in Table C.245. The CRFs from jurisdictions are provided in Table C.246.

Figure C.53: W-beam barrier

Source: ACP (2018).

Table C.245: Install semi-rigid barrier on roadside from no existing barrier CRFs from recent literature (% reduction)

Reference	Run-off-road	Comments
Park et al. (2016)	11 (4 stars)	All injuries

Table C.246: Summary of CRFs for installing semi-rigid barrier on roadside from no existing barrier (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight	50	75					
2	Off carriageway on straight, hit object	65	75					
3	Off carriageway on curve	50	75					
4	Off carriageway on curve, hit object	65	75					
7	All injuries*				40[1]		40 (2010) 35 (Austroads 2014)	11[2]
	Treatment life (years)	15						

1. *NZTA rated the 40% reduction with high confidence (30% for serious injury crashes and 10% for minor injury crashes).*
2. *This CRF is related to all types of crashes.*

The CRFs were revised to reflect the similar treatments outlined for head-on collisions. The revised values are outlined in Table C.247 .

Table C.247: CRFs for installing semi-rigid barrier on roadside from no existing barrier (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	50	50	70	70
16	703, 704, 904	Off carriageway on straight, hit object	65	65	80	80
18	801, 802	Off carriageway, on curve	50	50	70	70
19	803, 804	Off carriageway on curve hit object	65	65	70	70

C.5.19 INSTALL WIRE ROPE BARRIER ON ROADSIDE FROM NO EXISTING BARRIER (5.20)

Wire rope barriers – also known as flexible barriers – are supported by flexible posts (Figure C.54). This type of barrier is more forgiving than more rigid alternatives as it is better able to manage the kinetic energy vehicle occupants experience. The upright steel posts can pose a danger to motorcyclists however as a dislodged rider may slide under the wire and strike the upright metal post. Accordingly, on routes with high motorcycling volumes – particularly those with torturous geometry – a more motorcycle-friendly barrier is the preferred option, such a concrete barrier or w-beam with rub-rail.

Figure C.54: Wire rope barrier

Source: Austroads n.d.,

No CRFs were sourced from recent literature for this treatment . A summary of CRFs from jurisdictions is provided in Table C.248.

Table C.248: Summary of CRFs for installing flexible barrier on roadside from no existing barrier (% reduction)

No.	Crash type (DCA Group)	TMR	NSW RMS	VicRoads*	NZTA	SA	Austroads	Recent literature
1	Overtaking	85						
2	Off carriageway on straight	85	95	85				
3	Off carriageway on straight, hit object	90	95	85				
4	Off carriageway on curve	85	95	85				
5	Off carriageway on curve, hit object	90	95	85				
6	All casualty			76	65			
7	FSI crashes			32 (100 km/h) 61 (110 km/h)	80			
8	All casualty – (rural freeway)						79	
9	All casualty – (urban freeway)						86	
	Treatment life (years)	**20**		**20**				

** The VicRoads CRFs are based on providing wire rope barrier including on the median.*

The CRFs were revised to reflect similar treatments outlined for head-on collisions (Table C.249).

Table C.249: Summary of changes to CRFs for installing flexible barrier on roadside from no existing barrier (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	85	85	95	95
16	703, 704, 904	Off carriageway on straight, hit object	90	90	90	90

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
18	801, 802	Off carriageway, on curve	85	85	90	90
19	803, 804	Off carriageway on curve hit object	90	90	90	90

C.5.20 INSTALL CONCRETE BARRIER ON ROADSIDE FROM NO EXISTING BARRIER (5.21)

Concrete barriers – also referred to as rigid barriers – should only be used where no space for deformation of the barrier can be tolerated (iRAP (2010)). They are often used to protect key infrastructure (e.g. bridge pylons), where deformation may result in exposure to a more severe risk (i.e. a large vertical drop) or next to roadwork sites on high-volume roads.

Concrete barriers currently provide the highest level of containment of heavy vehicles and require little or no maintenance. A typical example of concrete barriers is shown in Figure C.55.

Figure C.55: Concrete barrier on highway

Source: Austroads (2019a).

No CRFs were sourced from recent literature for this treatment. A summary of CRFs from jurisdictions is provided in Table C.250. VicRoads considers rigid (concrete) barriers as roadside hazards and does not recommend them.

Table C.250: Summary of CRFs for installing rigid barrier on roadside from no existing barrier (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Off carriageway on straight	50	90					
2	Off carriageway on straight, hit object	65	90					
3	Off carriageway on curve	50	90					
4	Off carriageway on curve, hit object	65	90					
5	Out of control, on straight		90					
6	Out of control, on curve		90					
7	All casualty						43*	
	Treatment life (years)	**20**						

** Austroads specified a 43% reduction for all major treatments including barriers, cones, markings, and advance warning signs over no treatment.*

The CRFs were revised to reflect similar treatments outlined for head-on collisions (Table C.251).

Table C.251: Summary of changes to CRFs for installing rigid barrier on roadside from no existing barrier (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
15	502, 701, 702, 706, 707	Off carriageway on straight	50	50	65	65
16	703, 704, 904	Off carriageway on straight, hit object	65	65	70	70
18	801, 802	Off carriageway, on curve	50	50	65	65
19	803, 804	Off carriageway on curve hit object	65	65	70	70

C.5.21 REPLACE W-BEAM ON ROADSIDE WITH WIRE ROPE BARRIER (5.22)

This treatment has been excluded in line with the decision taken during the pilot workshop.

C.5.22 REPLACE CONCRETE BARRIER ON ROADSIDE WITH WIRE ROPE BARRIER (5.23)

This treatment has been excluded in line with the decision taken during the pilot workshop.

C.5.23 INSTALL GUIDE POSTS WITH REFLECTORS (5.24)

Guide posts assist the road user by indicating the alignment of the road ahead, especially at horizontal and vertical curves (iRAP (2010). They are usually set approximately 1 m from the edge of the road and equipped with reflectors to increase their effectiveness at night. Improving road delineation has been shown to reduce head-on and run-off-road crashes. A typical guide post is shown in Figure C.56.

Figure C.56: Flexible guide posts

Source: JMB Manufacturing (2017).

The CRFs sourced from recent literature for this treatment are provided in Table C.252. The CRFs related to run-off-road crashes have been applied to all off-carriageway crashes.

A summary of CRFs from jurisdictions is shown in Table C.253.

Table C.252: Install guide posts with reflectors CRFs from recent literature (% reduction)

Reference	Run-off-road	All crashes
Choi et al. (2015)		-19 (4 stars)
Dissanayake and Galgamuwa (2017)	10 (2 stars)	15
Weighted average	10	

Table C.253: Summary of CRFs for installing guide posts with reflectors (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	10 (L), 15 (H)	10					
2	Off carriageway on straight	10	10					10
3	Off carriageway on straight, hit object	10	10					10
4	Off carriageway on curve	10 (L), 20 (H)	10					10
5	Off carriageway on curve, hit object	10 (L), 20 (H)	10					10
6	Out of control, on straight	10	10					
7	Out of control, on curve		10					
8	All casualty			7			28 (2010)*	
	All casualty – night-time			28				
	Treatment life (years)	**5**		**15**				

** Rural, low confidence.*

While the Austroads research indicated a higher CRF may be appropriate, the low confidence of the result and the lower values used in the other jurisdictions as well as international research lead to conservative values being adopted (Table C.254).

Table C.254: Summary of changes to CRFs for installing guide posts with reflectors (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	10	15	10	10
15	502, 701, 702, 706, 707	Off carriageway on straight	10	10	10	10
16	703, 704, 904	Off carriageway on straight, hit object	10	10	10	10
17	705	Out of control, on straight	10	10	10	10
18	801, 802	Off carriageway, on curve	10	20	10	10
19	803, 804	Off carriageway on curve hit object	10	20	10	10

C.5.24 INSTALL CHEVRON ALIGNMENT MARKERS (CAMS) ON OUTSIDE OF CURVE (5.25) (WITH NO ADVISORY SPEED SIGNS)

Similar to guide posts, chevron alignment markers (CAMs) assist drivers to appreciate the geometry of the road by enhancing the delineation of curves (Figure C.59). They are generally installed on the outside of curves. This treatment involves installing CAMs at locations where there are no advisory speed signs.

Figure C.57: CAMs at night

Source: iRAP (2010).

The CRFs sourced from recent literature for this treatment are provided in Table C.255.

A summary of CRF values specified by jurisdictions is provided Table C.256. NSW RMS and VicRoads specified values without indicating the presence of speed signs; similarly, NZTA and Austroads (2012) both specified a 25% reduction in all casualty crashes for installing CAMs on horizontal curves but without indicating the presence of speed signs.

Table C.255: Install CAMs on outside of curve CRFs from recent literature (% reduction)

Reference	Run-off-road	All crashes
Choi et al. (2015)		27.9 (3 stars)
Dissanayake and Galgamuwa (2017)	12 (2 stars)	
Weighted average	10	30

Table C.256: Summary of CRFs for CAMs on curves (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	15(L), 45(H)	20					
2	Off carriageway on curve	15(L), 45(H)	25	30				10
3	Off carriageway on curve, hit object	15(L), 45(H)	25	30				10
4	Out of control, on curve	15	25					
	All casualty				25		25 (2012)	30
	Treatment life (years)	**10**		**15**				

Considering the consistency in values between Austroads (2012) and the jurisdictions it was decided in the workshop that the values be adopted. A summary of the changes are outlined in Table C.257.

Table C.257: Summary of changes to CRFs for CAMs on curves (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	15	45	25	25
18	801, 802	Off carriageway, on curve	15	45	25	25
19	803, 804	Off carriageway on curve hit object	15	45	25	25
20	805 - 807	Out of control, on curve	15	15	25	25

C.5.25 INSTALL CHEVRON ALIGNMENT MARKERS (CAMS) WITH EXISTING ADVISORY SPEED SIGNS (5.26)

No CRFs were sourced from recent literature for installing CAMs with existing advisory speed signs. A summary of CRFs specified by jurisdictions is provided in Table C.258. NSW RMS and VicRoads specified values without indicating the presence of speed signs; similarly, NZTA and Austroads (2012) both specified a 25% reduction in all casualty crashes for installing CAMs on horizontal curves but without indicating the presence of speed signs.

Table C.258: Summary of CRFs for installing CAMs with existing advisory speed signs (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	10(L), 25(H)	20					
2	Off carriageway on curve	10(L), 25(H)	25	30				
3	Off carriageway on curve, hit object	10(L), 25(H)	25	30				
4	Out of control, on curve	10(L), 25(H)	25					
	Casualty crashes						25 (2012)	
	Treatment life (years)	10		15				

Given the lack of identified research and the similarities with the previous treatment, it was decided to remove this treatment from the matrix.

C.5.26 GROOVING OF EXISTING PAVEMENT (5.27)

iRAP (2010) notes that the mechanical reworking of the existing surface — including grooving — can improve skid resistance, especially during wet weather. This treatment can reduce rear-end and run-off-road crashes.

The CRFs sourced from recent literature are provided in Table C.259. The only available CRF specifically for run-off-road crashes is 32.6% but this is for all crash severities.

The CRFs specified by jurisdictions are provided in Table C.260.

Table C.259: Grooving of existing pavement CRFs from recent literature (% reduction)

Reference	Run-off-road	All injuries
Merritt et al. (2015)	32.6 (1 star)	
		25.4 (2 stars)
Weighted average	30	25

Table C.260: Summary of CRFs for grooving of existing pavement (% reduction)

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
1	Head-on	25						
2	Off carriageway on straight							30
3	Off carriageway on straight, hit object							30
4	Off carriageway on curve	25(L),20(H)						30
5	Off carriageway on curve, hit object	25(L),20(H)						30
6	Out of control, on curve	25(L),20(H)						
7	All casualty						35 (2010 & 2012)	

No.	Crash type (DCA group)	TMR	NSW RMS	VicRoads	NZTA	SA	Austroads	Recent literature
	Treatment life (years)	**5**						

Given the values from recent literature as well as Austroads work, it was decided to increase the CRFs for this treatment slightly (Table C.261). Additionally, this treatment was clarified as being the provision of transverse grooving.

Table C.261: Summary of changes to CRFs for grooving of existing pavement (% reduction)

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
2	201, 501	Head on	25		30	30
18	801, 802	Off carriageway, on curve	25	20	30	30
19	803, 804	Off carriageway on curve hit object	25	20	30	30
20	805 - 807	Out of control, on curve	25	20	30	30

C.6 TREATMENT FOR REAR-END CRASHES

The existing TMR CRF table does not contain any treatments specifically targeting rear-end crashes. Therefore, all treatments proposed in this section will need to be considered for appropriateness for inclusion in the table and agreed with TMR.

The recent project completed by ARRB for NACOE (Luy & Affum 2018) reviewed treatments for reducing rear-end crashes on state-controlled roads. The report included a literature review of a number of treatments and CRFs detailing their effectiveness in reducing rear-end crashes. Given the recent nature of the report, it is considered the best source for the treatments it evaluates.

The report was preceded by a recent Austroads report (Austroads 2015c) which also looked into the underlying causes of rear-end crashes. This work included a number of countermeasures to help reduce the incidence of rear-end crashes. While the report was used as a source in Luy and Affum (2018) , it contains a number of additional treatments that will also be reviewed. Generally, it does not include CRFs for those treatments.

It is understood that the Transport Research Laboratory (TRL) is currently investigating the inclusion of rear-end crashes in the International Risk Assessment Programme (iRAP). This work highlights variable speed limits and freeway incident detection systems as potential treatments (TRL 2019).

A list of treatments is presented below and forms the basis of the review. Both the Luy and Affum (2018) and Beck (2015) reports build on a variety of sources, a list of which can be provided on request. Given the recent nature of these reports, the original sources have not been reviewed.

Based on the above, the following rear-end treatments have been investigated:

- Advance warning – active/dynamic signs
- Advance warning – static signs
- Clear sight distance obstructions
- Conversion of high-risk intersection to a roundabout
- Delineation
  - rumble strips
  - intersection-ahead pavement markings (or similar)
  - supplementary signage or traffic signals
  - improved street lighting
- Freeway incident detection systems
- Grade separation
- Headway treatments
- Improving intersection approach alignments

- Improving skid resistance
- Lane assignment signs and pavement markings
- Median-break closure
- Prohibit on-street parking
- Prohibit turning movements
- Red-light speed camera
  - replacement of red-light camera with combined red-light and speed camera
- Review signal operation and coordination
  - improved signal co-ordination
  - increased yellow and all-red phase time
  - dedicated turning phases
- Turn treatments
  - exclusive turn lanes (including provision and extension)
  - shielded acceleration lanes
  - bypass lanes
  - median turning lanes
  - slip lanes
  - increasing angle of turn
- Variable speed limits.

C.6.1 TREATMENTS ALREADY COVERED IN INTERSECTION OR ALL CRASHES

It is noted that many of the treatments identified as addressing rear-end risk also address intersection or all crashes as well, and in many cases rear-end is not considered to be the primary crash type addressed by the treatment. As these treatments are generally considered to be more applicable to the intersection or all crash types, they are to be included in the materials for those crash types and are not be covered here. These treatments include:

- Advance warning – active/dynamic signs
- Advance warning – static signs
- Clear sight distance obstruction
- Delineation – rumble strips
- Delineation – supplementary signage or traffic signals
- Delineation – supplementary signage or traffic signals
- Delineation – improved street lighting
- Grade separation
- Lane assignment signs and pavement markings
- Median-break closure
- Prohibit turning movements
- Review signal operation and coordination – dedicated turning phases
- Turn treatments – exclusive turn lanes (including provision and extension)
- Shielded acceleration lanes
- Turn treatments – bypass lanes
- Turn treatments – median turning lanes
- Turn treatments – increasing angle of turn.

C.6.2 DELINEATION

Delineation takes a variety of forms and is aimed at enhancing the driver’s ability to identify the appropriate vehicle path and speed.

Intersection ahead pavement markings (or similar)

This treatment consists of pavement markings alerting drivers to the presence of an intersection further downstream. Improving driver awareness of an intersection or high-use property access can help to reduce the incidence of harsh braking as well as highlight the potential for slowing traffic to following drivers.

No CRFs were identified in the Austroads reports, nor did any of the jurisdictions have existing CRFs for this treatment type.

International literature identified is outlined in Table C.262.

Table C.262: Intersection ahead avement markings CRFs from international literature

Reference	Type of pavement markings	Severity	All crashes	Angle crashes	Rear-eEnd
Torbic et al. (2015) (3 Stars)	'Stop ahead' pavement markings, rural environment, 5700 vpd	All	67	92	95
		All casualty	76	88	96
	'Stop ahead' pavement markings, rural environment, 4800 vpd	All	64*	74	89
		All casualty	69	71	86
Average		All	65%	85	90
		All casualty	75%	80	90

**It is noted that this CRF was classified with a 4 star quality rating.*

While the study outlined in Table C.262 identified this type of treatment as being highly effective, it is unclear whether the sites studied had significant sightline or other issues before being treated. The CRFs provided – including almost eliminating rear-end crashes – seem improbably high.

Given the lack of information on this treatment, and the lack of current use in Australia and Queensland more broadly, it was decided not to include the treatment in the matrix.

C.6.3 FREEWAY INCIDENT DETECTION SYSTEMS

Freeway incident detection systems automatically detect queuing and/or crashes and relay this information to drivers usually in the form of variable message signs (see also dynamic warning signs).

Transport Research Laboratory (2019) highlighted a number of case studies for this type of treatment and recommended a CRF of 15% for rear-end crashes .

No other recent research on this topic was identified and this type of treatment was not covered in the other jurisdictions' CRFs.

Table C.263: Freeway incident detection system CRFs from international literature

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Rear-end								15

This treatment is specific to motorways and is unlikely to be installed purely on the basis of addressing rear-end crashes. Given this, it was decided not to include the treatment in the CRF matrix.

C.6.4 HEADWAY TREATMENTS

Vehicle headway is the measure of the distance or time between consecutive vehicles. Leaving inadequate headway (often termed tailgating) reduces the time available for drivers to react to a sudden stoppage of the vehicle in front and is a major cause of rear-end crashes. Treatments to combat short headways are most applicable on high-speed roads where there is less stoppage caused by intersections. Providing headway guidance markers and signs, advisory signs such as 'help prevent crashes, please don't tailgate', and vehicle activated signs detecting headway can all be effective infrastructure treatments to combat rear-end crashes (Luy & Affum 2018).

A study in Israel cited by Luy and Affum (2018) indicated a CRF of 40–45% for an automatic headway detection system used in tandem with law enforcement to prevent tailgating.

Beck (2015) also highlighted the potential for tailgating treatments to reduce rear-end crash risk, however no specific CRFs were provided. The report noted a study undertaken in Victoriathat trialled chevron markings with complementary signage advising drivers of suitable following distances but the study noted no significant improvement in safety performance.

No other recent studies were identified, and this treatment is not included in the CRF tables of the other jurisdictions (Table C.264).

Table C.264: Headway treatments

No.	Crash type (DCA gGroup and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Luy & Affum	Recent literature
1	Rear-end							40-45	

The lack of specific information on this treatment – with the only CRF available being in a single study in Israel that relied on complementary enforcement – precludesits inclusion in the matrix.

C.6.5 IMPROVING INTERSECTION APPROACH ALIGNMENTS

Crests and curves (or a combination of both) may obstruct sight lines to the road ahead, intersections and the back of queues, which reduces the available stopping sight distance for drivers. Road realignment is an expensive treatment option to clear obstructions but may be warranted if less expensive options are not effective (Luy & Affum 2018).

Luy and Affum (2018) cite a 30–50% and 40–50% reduction in rear-end crashes for horizontal and vertical alignment improvements respectively.

No other recent CRFs were identified. None of the jurisdictions had CRFs relating to the alignment of the intersections approaches, however general alignment CRFs are covered within the run-off-road materials.

Table C.265: Improving intersection approach alignment summary of literature

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Luy & Affum	Recent literature
1	Rear-end – horizontal alignment improvements							30-45	
2	Rear-end – vertical alignment improvements							40-50	

While there is a rear-end component to this measure, intersection approach alignments were considered more important to intersection-style crashes, and accordingly it is not included as a separate rear-end treatment.

C.6.6 IMPROVING SKID RESISTANCE

By improving skid resistance of the road surface, vehicles can stop in shorter distances when braking.

Luy and Affum (2018) cite a CRF of 25–40% for all crashes for improving skid resistance and 60–70% for the application of high–friction surfacing. Beck (2015) cites a CRF of 30–40% for rear–end crashes, improving to 30–60% for steep gradients.

Austroads (2012) outlines a CRF of 35% for improved skid resistance.

A number of international studies were identified that had produced CRFs based on crash severity, crash types, baseline conditions and treatment types. The results are presented at Table C.266. Crash severity has been limited to all injury and all crashes, noting other literature sources included property damage only figures as well as injury only figures (excluding fatalities) which were considered less relevant (outlined at Table C.267 for reference).

Table C.266: Improved pavement friction treatment CRFs (all injury crashes, all crash types)

Treatment	CRF (%)
Improve pavement friction (chip seal)	0
Improve pavement friction (diamond grinding)	10
Improve pavement friction (OGFC – open graded friction course)	5

Treatment	CRF (%)
Improve pavement friction (microsurfacing)	-10
Improve pavement friction (thin HMA – hot mix asphalt)	-5
Improve pavement friction (slurry seal)	5
Improve pavement friction (UTBWC – ultra thin bonded wearing course)	10
Improve pavement friction (grooving)	25
Average	5

Note: All Injury constitutes K (fatal), A (serious injury), B (minor injury), C (possible injury) as per CMF Clearinghouse classifications.
Source: Based on Merritt et al. (2015), Buddhavarapu et al. (2015) and Musey et al. (2017).

Table C.267: Improved pavement friction treatment CRFs (all crash severities)

Treatment	CRF (%) by Crash Type				
	All	Wet road	Run-off-road	Run-off-road, wet road	Dry weather
Improve pavement friction (chip seal)	-5	10	5	30	-5
Improve pavement friction (Diamond grinding)	15	15	35	25	15
Improve pavement friction (OGFC-open graded friction Course)	5	20	20	40	0
Improve pavement friction (microsurfacing)	0	5	-5	0	-10
Improve pavement friction (Thin HMA-Hot Mix Asphalt)	-5	5	-20	10	-10
Improve pavement friction (slurry seal)	5	25	40	40	5
Improve pavement friction (UTBWC-ultra thin bonded wearing course)	10	15	-10	20	0
Improve pavement friction (grooving)	20	-	35	-	40
Improve pavement friction (HFS-high friction surfacing)	30*	65*	-	-	-
Install permeable friction course (PFC)	-	-5	-	-	-
Install high friction surface treatment (HFST)	0	-	-	-	-
Average by crash type	**5**	**10**	**15**	**25**	**5**
Average overall			**10**		

Based on: Merritt et al., 2015, Buddhavarapu et al., 2015 and Musey et al., 2017.
** High friction surfacing is considered a different type of treatment than standard improvement to surface friction and has been excluded from the averages.*

Both NSW and SA had improved skid resistance in their CRF tables. A summary of CRFs is presented in Table C.268 .

Table C.268: Summary of improvements to skid resistance CRFs

No.	Crash type (DCA group and environment)	TMR	NSW RMS[1]	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches		35						
2	Head-on		35						
3	Opposing vehicles turning		35						

No.	Crash type (DCA group and environment)	TMR	NSW RMS[1]	VicRoads	WA	SA	NZTA	Austroads	Recent literature
4	Rear-end		50						
5	Parallel lanes turning		-						
6	U-turn		-						
7	Hit pedestrian		30						
8	Out of control, on curve		40			30			
9	All crashes, all environments							35 (2012)	5% (average)
10	All casualty crashes, all environments								5
11	All casualty crashes, wet weather								10
12	Run-off-road								15
13	Run-off-road, wet weather								25
14	Dry weather								5

1: RMS CRFs are for crashes in wet weather only.

As noted previously, high friction surfacing is considered a separate measure to standard improvements to road surfacing. TMR has CRFs for this treatment type, as does VicRoads. The CRFs for high friction surfacing are presented at Table C.269.

Table C.269: High friction surfacing CRFs

No.	Crash type (DCA group and environment)	TMR[1]	NSW RMS	VicRoads	WA	SA	NZTA	Austroads (ref year)	Recent literature
1	Intersection, adjacent approaches	5							
2	Head-on	10							
3	Opposing vehicles turning	5							
4	Rear-end	40							
5	Parallel lanes turning								
6	U-turn								
7	Hit pedestrian	15							
8	Out of control, on curve	20							
9	Casualty crashes – all environments – high PSV (polished stone value) overlay			20					30[3]
10	Casualty crashes – all environments – calcined bauxite			40					
11	Casualty crashes – wet weather – high PSV overlay			40					65[3]
12	Casualty crashes – wet weather – calcined bauxite			50					
	Treatment life (years)	5		5/10[2]					

1: TMR values are for calcined bauxite.

2: 5 years for high PSV overlay, 10 for calcined bauxite.

3: Type of high friction surfacing not specified.

Discussions from the workshop noted that improvements to skid resistance would typically be undertaken as part of a road management project rather than as a road safety project, and as such they were not to be included in the matrix.

The high fiction surfacing CRFs adopted are shown in Table C.270.

Table C.270: Adopted high friction surfacing CRFs

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches	5	5	5	5
2	201, 501	Head on	10	10	10	10
3	202 - 206	Opposing vehicles turning	5	5	5	5
4	301 - 303	Rear end	40	40	20	20
12	001 - 009	Hit pedestrian	15	15	20	20
13	605	Permanent obstruction	5	5		
14	609, 905	Hit animal	5	5		
18	801, 802	Off carriageway, on curve	20	20	40	40
19	803, 804	Off carriageway on curve hit object	20	20	40	40
20	805 - 807	Out of control, on curve	20	20	40	40

C.6.7 PROHIBIT ON-STREET PARKING

Banning parking may improve sight lines and reduce traffic friction, which in turn may reduce rear-end crashes. This treatment has been covered under 'other' crashes.

C.6.8 REPLACE RED-LIGHT CAMERAS WITH RED-LIGHT/SPEED CAMERAS

Red-light cameras have been shown to increase the incidence of rear-end crashes (Austroads 2015c). Luy and Affum (2018) cite a 19% increase in rear-end crashes due to the installation of red-light cameras.

Beck (2015) notes that the use of combined red-light/speed cameras where previously there was only a red-light camera can eliminate this effect.

A recent study was identified on combined cameras and the average CRFs for each crash type are detailed in Table C.271 .

Table C.271: Combined red-lght and red-light/speed camera CRFs

Crash type	CRF by severity	
	All	K (fatal) and A (serious injury)
All	5%	5%
Sideswipe	5%	10%
Rear-end	-45%	-
Angle, left turn	5%	-

Source: Based on De Pauw et al. (2014).

It is noted that this study is from the United States and so 'angle, left turn' would be the equivalent of a right turn in Australia. It is noted that the findings shown in the table contradict Beck (2015), indicating a significant increase in rear-end crashes.

VicRoads wasthe only authority to have combined red-light and speed cameras in its CRF table (Table C.272).

Table C.272: Fixed red-light and speed camera (combined) CRFs

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads	Recent literature
1	Intersection, adjacent approaches								5

2	Head-on								
3	Opposing vehicles turning								
4	Rear-end								-45%
5	Parallel lanes turning								
6	U-turn								
7	Hit pedestrian								
8	Out of control, on curve								
9	All casualty crashes			26					
10	All casualty crashes – targeted approach			40					
11	All								5
1214	Sideswipe								5
	Treatment life (years)			10					

The installation of new fixed cameras is not the responsibility of the TMR Safer Road Infrastructure team and it was the decision of workshop attendees not to include the treatment in the CRF table.

In addition to the 'install fixed digital speed and red-light camera' CRF, VicRoads also outlined a CRF for upgrading from a sole red-light camera to combined red-light/speed camera.

No other information on this treatment type was identified.

Table C.273: Fixed red-light camera to combined fixed digital red-light/speed camera

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads (ref year)	Recent literature
1	All casualty crashes			19					5
2	Serious injury crashes			72					
3	Right-angle/right-through crashes			41					
4	Rear-end crashes			20					
	Treatment life (years)			10					

Despite the limited amount of information, it was decided that this treatment – which has the potential to reduce the detrimental impacts of red-light cameras – was worthy of inclusion in the matrix and the VicRoads values should be adopted as set out in Table C.274 .

Table C.274: Fixed red-light camera to combined fixed digital red-light/speed camera

DCA group	Crash Type (DCA Code/Description)		Old Values		New Values	
			Low Speed	High Speed	Low Speed	High Speed
1	101 - 109	Intersection, adjacent approaches			40	40
3	202 - 206	Opposing vehicles turning	New treatment		40	40
4	301 - 303	Rear-end			20	20

C.6.9 REVIEW SIGNAL OPERATION AND COORDINATION

Changes to signal operation and coordination help to manage and improve traffic flow through an intersection, reducing stop-start traffic and reducing rear-end crashes as a result.

Luy and Affum (2018) cite a 55% reduction in casualty crashes for changing signal phases. It is noted that this reduction is likely to be highly subject to the base conditions and no specifics were given on what the operation and coordination involved.

Improved signal coordination

Coordination of signals along a route can reduce the frequency of stops. This reduces speed differentials along the route reducing the risk of rear-end crashes (Austroads 2015c).

Austroads (2012) provides a CRF of 15% (all crashes) for linking signals.

A review of recent literature noted a single study from the USA (Williamson et al., 2018, see Table C.275).

Table C.275: Improved signal coordination CRFs – international literature

Area type	CRF%
Suburban (2 star)	10
Urban (2 star)	5
Urban and suburban (3 star)	20
Average	15

It is noted that the values above are averages for each of the area types. Four values were recorded in the study for suburban conditions and while the majority showed small negative CRFs (increase in crashes) one value showed a 62% reduction. This value was considered an outlier and discarded. Other values were presented for injury only (excluding fatalities and property damage) and property damage only crashes. These values have been excluded but can be provided on request.

VicRoads and NZTA both list a 15% CRF for this treatment, and VicRoads also notes a 15-year treatment life (Table C.276).

Table C.276: Summary of signal coordination CRFs

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Austroads (ref year)	Recent literature
1	All casualty crashes			15			15		15
	Treatment life (years)			15					

Through discussion at the workshop it was decided not to include this treatment as it was not considered to be primarily safety focused . It was also acknowledged that signal coordination may have the adverse effect of raising mean speeds, to the detriment of safety.

C.6.10 TURN TREATMENTS – SLIP LANES

Slip lanes allow left-turning traffic to be dissipated faster, thus reducing traffic queues that contribute to rear-end crashes (Austroads 2015c).

Luy and Affum (2018) cited a 69% reduction in rear-end crashes when using slip lanes at major signalised intersections (Table C.277).

No other recent literature on this treatment was identified, nor was this treatment identified in any of the other jurisdictions, however MRWA does note in its table 'There is increasing evidence that dedicated left turn lanes and slip lanes have detrimental safety effect on pedestrian safety.'"

Table C.277: Summary of slip lane CRFs

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Luy & Affum (2018)	Recent literature
1	Rear-end crashes							69	

This treatment was discussed in the workshop and it was noted that the TMR view on slip lanes accords with that of MRWA in that they can be detrimental to pedestrian safety. TMR no longer supports the use of slip lanes and they are not to be included in the matrix.

C.6.11 VARIABLE SPEED LIMITS

The context of this treatment realtes to variable speed limits relate to their use on motorways. In times of congestion, speeds can be lowered to smooth traffic flow and reduce differential speeds. As traffic flow disruptions are minimised, the risk of rear-end collisions is reduced (Austroads 2015c).

Luy and Affum (2018) cite a 30% reduction in all crashes for this treatment.

Two recent studies were identified on variable speed limits: Pu et al. (2017) and Dutta et al. (2018) – see Table C.278. It is noted that the latter study was evaluating the use of variable speed limits in combination with other ITS treatments. Accordingly, the impact of variable speed limits alone could not be ascertained and these CRFs have been discounted. These can be provided on request.

Table C.278: Variable speed limit CRFs from international literature

Crash type	Crash severity	CRF%
All	All	30
	K (fatal), A (serious injury), B (minor injury)	20

Source: Pu et al. (2017).

None of the jurisdictions currently have CRFs for this treatment.

Table C.279: Summary of variable speed limit CRFs

No.	Crash type (DCA group and environment)	TMR	NSW RMS	VicRoads	WA	SA	NZTA	Luy & Affum (2018)	Recent literature
1	All severity, all crashes							30	30
2	All injury crashes								20

Given the narrow application of this treatment, it was decided not to include it in the matrix.

APPENDIX D WORKSHOP ATTENDEES

- From Transport and Main Roads Queensland:
  - Andrew Burbridge
  - Dieu Vuong
  - Simon Harrison
  - Michael Gilles
  - Jon Douglas
  - Mark McDonald
  - Bernard Worthington
  - Pooya Saba
  - Michael Langdon
  - Paul Cummins
  - John Oppes
  - Delia Atkinson
  - Daniel Wong
  - Lachlan Moir
  - Andrew Pine
  - Emily Plath
  - Chelsee Klaassen
- From the Australian Road Research Board:
  - Tia Gaffney
  - Joseph Affum
  - David Milling
  - Brayden McHeim
  - Trevor Wang