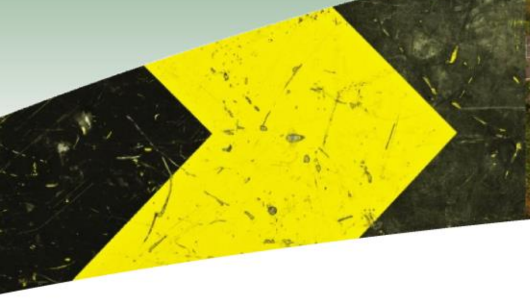
Road Attribute Risk Factors
Intersection Type



This factsheet describes the road attribute risk factors used in the iRAP methodology for Intersection Type. Intersection Type records the presence and type of intersections with gazetted/adopted roads.

About risk factors

Risk factors, sometimes called crash modification factors (CMF), are used in the iRAP Star Rating methodology to relate road attributes and the risk of death or serious injury in a crash. Risk factors (or CMF) are described by the Crash Modification Factor Clearing House as follows:

> *A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.*
>
> *For example, an intersection is experiencing 100 angle crashes and 500 rear-end crashes per year. If you apply a countermeasure that has a CMF of 0.80 for angle crashes, then you can expect to see 80 angle crashes per year following the implementation of the countermeasure (100 x 0.80 = 80). If the same countermeasure also has a CMF of 1.10 for rear-end crashes, then you would also expect to also see 550 rear-end crashes per year following the countermeasure (500 x 1.10 = 550).*

Related documents

This factsheet should be read in conjunction with:

- *Star Rating Roads for Safety: The iRAP Methodology.*
- *Safer Roads Investment Plans: The iRAP Methodology.*
- *Star Rating Coding Manual.*
- *Road Safety Toolkit (http://toolkit.irap.org).*

Risk factors

Risk factors by road attribute category, road user type and crash type

Intersection type	Vehicle occupant (and motorcyclist) – likelihood	Vehicle occupant (and motorcyclist/ bicyclist) – severity	Pedestrian - likelihood	Bicyclist - likelihood
Merge lane	6	15 (20)*	1.05	40
Roundabout	15 (30)	15 (30)*	1.5	150
3-leg (unsignalised) with protected turn lane	13 (17)	45	1.1	45
3-leg (unsignalised) with no protected turn lane	16 (20)	45	1.1	55

Intersection type	Vehicle occupant (and motorcyclist) – likelihood	Vehicle occupant (and motorcyclist/ bicyclist) – severity	Pedestrian - likelihood	Bicyclist - likelihood
3-leg (signalised) with protected turn lane	9 (9)	45	1.1	30
3-leg (signalised) with no protected turn lane	12 (14)	45	1.1	40
4-leg (unsignalised) with protected turn lane	16 (16)	50	1.2	55
4-leg (unsignalised) with no protected turn lane	23 (26)	50	1.2	80
4-leg (signalised) with protected turn lane	10 (10)	50	1.2	35
4-leg (signalised) with no protected turn lane	15 (16)	50	1.2	50
Unused code (non-major inters.)	0	0	1.0	0
None	0	0	1.0	0
Railway Crossing - passive (signs only)	1 (1)	150	1.0	3
Railway Crossing - active (flashing lights/boom gates)	0.5 (0.5)	150	1.0	1
Median crossing point - informal	0.5 (0.5)	45	1.1	2
Median crossing point - formal	0.3 (0.3)	45	1.1	1
Mini roundabout	16 (16)	35	1.3	55
** Commercial access 1+	[2.0]	50	1.01	1.01
** Residential access 1+	[1.3]	50	1.01	1.01
** Residential access 1 or 2	[1.0]	50	1.01	1.01

* Bicyclist values differ for merge lanes (40) and roundabouts (150).
** Values in square parenthesis feature as a separate attribute in the vehicle occupant and motorcyclist models (Property Access Points); values for commercial and residential access feature as part of Intersection Type only in the bicycle model.

Selection of risk factors

Vehicle occupant and motorcyclist – likelihood

It is assumed that the likelihood of a severe crash for vehicle occupants is less than for motorcyclists at most intersections. At roundabouts, the likelihood factor for motorcyclists is double that of vehicle occupants.

The road attribute risk factors for this attribute were derived by relating the risk at one junction type to another from information about the general effect of introducing signals and protected turn lanes (either where there are signals or where these do not exist). By implication, using the values for product of likelihood and severity, the ratio of crashes at 4-leg and 3-leg intersections is shown the table below. This shows that 4-leg intersections are expected to have around 20-60% more deaths and serious injuries than 3-leg intersections.

Risk values of different 3-leg and 4-leg intersections

	3-leg product of likelihood and severity risk values	4-leg product of likelihood and severity risk values	Ratio 4-leg:3-leg product of likelihood and severity risk values
Unsignalised, with protected turn	585	800	1.37
Unsignalised, no protected turn	720	1150	1.60
Signalised, with protected turn	405	500	1.23
Signalised, with no protected turn	540	750	1.39

Pedestrian – likelihood

The likelihood of a pedestrian death or serious injury is assumed to be about one-tenth higher at 4-leg intersections than 3-leg intersections and 50% higher at roundabouts.

Bicyclist - likelihood

Likelihood values for bicyclists are 2-4 times higher than those of vehicle occupants and substantially so at merge lanes (more than a factor of 6) and roundabouts (10 times).

Vehicle occupant - severity

Designed angles of approach mean that if an impact occurs, merge lanes and roundabouts provide a relatively forgiving impact at an obtuse angle, the impact at mini-roundabouts even more so on the basis that they are designed to reduce entry speed even more. (Impacts at railway crossings are judged to have the potential for much higher severity.) SWOV research (http://www.swov.nl/rapport/Factsheets/UK/FS_Roundabouts.pdf) concludes: "A roundabout reduces the number of conflicts at an intersection and leaves only the lateral conflicts. A roundabout also reduces the speed of approaching traffic. During the period 1999-2005, the conversion of intersections into roundabouts led to a reduction of about 46% in the number of severe casualties. On rural roads, replacing an intersection, either a priority intersection or a signalized one, by a single-lane roundabout led to a 70% reduction in injury crashes, including those with slight injury. This reduction of 70% in injury crashes can also be assumed valid for turbo-roundabouts. It is necessary to take the mobility effects and extra space needed into account. The pollution effects, i.e. harmful exhaust emission and noise, are positive if a roundabout replaces a signalized intersection. When a roundabout replaces an unsignalized intersection, the result is slightly more exhaust emission, but less noise hindrance. The conversion of an intersection into a roundabout is cost-effective, as is changing priority for cyclists into no priority".

Motorcyclist and bicyclist – severity

Severity values for motorcyclists and bicyclists are assumed to be identical and the same as those for vehicle occupants other than that they are assumed not to gain as much benefit as vehicle occupants from the angled impacts (as opposed to brutal right-angled impacts) common at roundabouts – that is, the severity of impact for a motorcyclist or bicyclist being struck at an acute angle may differ little compared with a right-angled impact.

Crash modification factors and likely effect of junction change

Countermeasure	Crash Modification Factor from literature	3-leg intersection – modeled effect *	4-leg intersection – iRAP modeled effect *
General effect of introducing traffic signals where no signals existed previously	0.7 – Turner et al (2012)	0.75	0.65
Installing a protected turn where signals already exist	0.7 – Bui et al (1991) and Turner et al (2012)	0.75	0.67
Installing a protected turn at unsignalised intersection	0.65 – Austroads (2012)	0.81	0.70

* Based on before and after quotient -- ($likelihood_{AFTER}$*$severity_{AFTER}$)/($likelihood_{BEFORE}$*$severity_{BEFORE}$)

Effect of the Provision of New Signals

According to Turner et al (2012):

> *"In relation to all crashes, seven studies provided general crash reductions for installation of traffic signals. However, the figure from Tasmania was based on only two sites, and appeared to be an outlier. Therefore it was omitted. Based on the remaining six studies, a reduction of 30% is recommended. Due to the variability in results, there is a low level of confidence in this figure.*
>
> *In relation to crash types, three studies provided figures for reductions in angle crashes and two studies provided results for rear-end crashes. Studies showed mixed results for rear-end crashes, with many showing increases in this crash type. Based on these results a general reduction of 50% for angle crashes, and a 30% increase in rear-end crashes are recommended.*

Installation of signals is likely to result in an increase in rear-end crashes, but reduce angle and pedestrian-type crashes, which are often higher severity.

A number of studies provided figures for installing signals at three and four-leg intersections. There appears to be greater benefit for signalisation of four-leg intersections, which is not surprising as movements at four-leg intersections are generally more complicated than at three-leg intersections.

A number of studies also provided figures for the provision of signals at urban and rural intersections. Based on these, there are some mixed results, however there appears to be great improvement for rural installations."

One study considered the provision of fully controlled right-turns, provision of partial control and changing partial to full control (Bui et al., 1991). The study (p.25) observed that 'full control of right-turns yields poorer intersection performance than partial control under virtually all conditions. The differences in performance, particularly between partial and full control, were slight and are unlikely to negate the safety advantages'.

Five studies provided general reductions for the provision of fully controlled right-turns (Corben et al. (1990), Bui et al., Agent et al., Corben et al. (2001) and Gan et al.). Based on these, a reduction of 35% is expected (with a medium level of confidence). A number of studies also provided guidance for different crash types. Based on these, a reduction of 60% for right through crashes (low confidence) and 45% for adjacent direction crashes (low confidence) is recommended. There is mixed information regarding the effect on rear-end crashes, and so a recommended crash reduction has not been provided.

Five studies provided figures for the provision of partially controlled right-turns. However, only one study provided a general figure of 10% (Agent et al.). There is low confidence in this figure as it is only based on one study.

Two studies provided figures for changing partial to full control (Bui et al. and Elvik et al.). Based on these, a general crash reduction of 70% is suggested.

Right turn without signals

Four studies gave figures for right-turn, not at signals (Creasey and Agent, Agent, Shen and Gluck). The figures were 25%, 35%, 32%, 63%. The average from these figures was a 38% reduction, but given that the figure from Gluck appeared to be an outlier, this was rounded down to 35%. It was noted that the benefit identified in a number of studies (see e.g. Gluck) was generally greater for sites that were not signalised, and this issue requires further investigation (Austroads, 2010 – page 49).

Right turn at signals

Three studies provided figures for right-turn at signals. The figures were 30%, 35% and 41%. The average for these values is 35%."

Background research and model development

Likelihood

Lynam (2010) described how the likelihood risk factors in earlier versions of the iRAP model were derived.

"Numerous studies have shown the importance of junction density to crash rate. For example in US models (eg Vogt and Bared, 2000) driveway density is shown to be a significant variable. In Britain, Walmsley and Summersgill (1998) suggest adding one extra access to a single carriageway causes up to 1% increase in crashes, but on dual carriageways causes 2-3% increase in crashes. Gluck et al (1999) suggest that compared with a road with 10 access points per mile, roads with 40 access points have double the crash rate, and with 60 access points three times the rate. Hughes et al (1997) suggest that increasing the distance between grade-separated junctions leads to reductions in crash frequency on both on-ramps and off-ramps. Ramps with change in vertical alignment lead to more crashes than level ramps.

Until further information is available, most of the factors and their risk values are assumed to be generally the same for motorcyclists as for vehicle occupants. One specific difference is the use of a likelihood factor twice as high as that for cars, for motorcycles at roundabouts.

Davies et al (1997) shows data from Kennedy (1997) for urban roundabouts suggesting that crash involvement rates might be twice as high for motorcyclists and three times as high for pedal cyclists at 4-arm *roundabouts compared with traffic signals or crossroads. Differences may be less for three arm roundabouts, but in all cases the data are confused as the factors appear to vary with relative car and pedal cycle flows, with rates per cycle flow being higher where other vehicle flows are higher and cycle flows are lower.*

Analyses in Davies et al (1997), based on Maycock and Hall (1984) analysis of pedal cyclist crashes at roundabouts, suggest that if cycle flow is increased fourfold, then cyclist crash rate is reduced by about 40%. Part of this effect was built into the flow factor risk values in earlier models where a factor of 1.75 is used for high flows compared with a factor of 1 for medium flows - but the extent to which this reflects the true differences will depend in part on the interpretation of High, Medium, and Low flows in each country.

Median islands of various types can also be used as spot treatments, typically at intersections. This is incorporated within the attribute "Intersection Channelisation". Types of treatments include splitter islands and median islands on the major through road. These are designed to separate the opposing traffic movements, channelise traffic to a defined travel path, limit vehicles' turning speed by restricting the turning radius, and sometimes to provide a staging point for crossing vehicles and pedestrians.

Lynam commented that this is generally well-researched area with good data available for vehicle occupants, but less information for other road-users.   The selection of risk factors is based upon best-available information, but those intersection types that are less common or where risk is low are typically under-researched. iRAP monitors research worldwide and will update risk values if better data become available.

The iRAP model provides estimates of risk only for those categories shown. Risk estimates for minor junctions and driveways is dependent to some extent upon assumptions of inflow from their arms.

<u>Severity</u>

Lynam (2010) also described how the severity risk factors in earlier versions of the iRAP model were derived.

"The primary focus of the basic Road Protection Score (the basis of the Star Rating) was to assess the extent to which road design mitigates severe injury, not the extent to which it reduces the number of crashes. It is necessary therefore to devise an assessment which relates to the likely severity resulting from different junction types. The focus for the assessment is also the protection provided to vehicle occupants. Thus, roundabouts should score well as they result in very few fatalities to vehicle occupants, although they present greater risk of severe crashes to two-wheeler riders than to vehicle occupants. A scoring regime was thus constructed based on the biomechanical principles associated with the effect of speed and angle of impact on severity of injury to vehicle occupants.

<u>Angle of impact</u>

Risk factors for angle of impact and impact speed were developed in two parts. First, for each category of intersection design, an assessment was made of the angle of merging and the extent to which this might reduce collision speed. For example, for motorway merging, impact speeds would be expected to be very little different from the speed of traffic on the motorway. For "merging" manoeuvres where either a very short merging lane or no merging lane at all was provided, collision speeds were assumed to be half or three quarters of the speed limit; this assumes that drivers would only emerge at these junctions if they thought they had space to do so, and collisions would occur in situations where this judgement was incorrect, but would still enable some slowing of approaching traffic. Where, as with roundabouts, merging vehicles were required to adjust their line of approach through say 45 or 60 degrees on entry, collision speeds were assumed to be at quarter or half of the traffic speed on the joining road. Thus for example, a roundabout, on a road with 90km/h speed limit, which requires vehicles to deflect 60 degrees on their approach, should be assessed on the speed/risk curve for a speed of about 45kph.

<u>Impact speed</u>

Secondly, the starting point of unit risk, on the speed/risk curve is set at different speeds according to the potential angle of impact. These speeds are again chosen to relate to vehicle occupant injury resulting from vehicle impact tests ie for frontal impact unit risk is assumed at 70kph, for 90 degree side impact at 50kph, and for 60 degree impact at 60 km/h. By combining these two sets of assumptions, a relative risk table is constructed for different junction types on roads with different speed limits. In theory, any junction type could be added to this table, providing an assumption is made of the extent to which the junction affects the speed of approaching vehicles and their angle of impact.

The scoring regime developed in this way can be compared with data on the relative proportion of vehicle occupant fatalities occurring at different types of junction. Data from Germany (Eckstein and Meewes, 2002) show ratios between number of seriously injured persons and the number of slightly injured persons varying between 0.1 for small roundabouts controlled by give way signs, to 0.3 to 0.4 for traffic light junctions, and 0.5 for junctions with give way control by traffic signs only.

The "protection" afforded by different junctions is a relatively new concept for most road engineers although the principles on which the idea is based have been researched to some extent (see above) and will become more extensively in the future as Safe System designs become accepted."

Tabulations of severity rates at British junctions were used in formulating the original risk factors, together with estimations from first principles. This will continue to be a limitation in the model until better results become available.

Risk factors in earlier versions of the iRAP model

Intersection type	Likelihood vehicle occupant, motorcyclist and bicyclist	Protection vehicle occupant, motorcyclist and bicyclist
Merge lane	20	1
Roundabout	50*	1
3-leg (unsignalised) with protected turn lane	35	3.25
3-leg (unsignalised) with no protected turn lane	45	3.25
3-leg (signalised) with protected turn lane	30	3.25
3-leg (signalised) with no protected turn lane	35	3.25
4-leg (unsignalised) with protected turn lane	45	3.5
4-leg (unsignalised) with no protected turn lane	70	3.5
4-leg (signalised) with protected turn lane	35	3.5
4-leg (signalised) with no protected turn lane	45	3.5
Unused code (non-major intersection)	1	3.25
None	0	0
Railway Crossing - passive (signs only)	3	50
Railway Crossing - passive (signs only)	1	50
Median crossing point - informal	2	3.25
Median crossing point - formal	1	3.35
Mini roundabout	--	--

* 50 is the value for vehicle occupants – values for motorcyclist are 100 and for cyclist 150

References

The following publications are the primary references used in the selection of the iRAP road attribute risk factors. A complete list of citations is available in: *iRAP Road Attribute Risk Factors: Full Reference List.*

Elvik, R, Hoye A, Vaa, T, and Sorensen, M. (2009). *The Handbook of Road Safety Measures, Second Edition.* Emerald Group Publishing Limited. ISBN 978-1-84855-250-0.

Lynam, D (2012). Development of Risk Models for the Road Assessment Programme. RAP504.12 *and TRL Report CPR1293, Published by iRAP and TRL and* available at: http://www.trl.co.uk and at http://www.irap.org.

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