What factors actually affect crash severity and how can road safety programs be better targeted?

Stephen Levett, Dr. David Saffron, Joyce Tang, Dr. Soames Job

Safer Roads Branch, NSW Centre for Road Safety

NSW Roads & Traffic Authority

Abstract

The aim of this study was to develop a methodology that would better focus scarce road safety resources to fix those areas of the road network that have the greatest number of fatal and serious injury crashes.

Cost-benefit analysis (CBA) is used to prioritise black spot projects with the economic benefit of a remedial treatment being the difference between predicted costs of crashes with and without the proposed treatment. In NSW and AusLink CBA a crash by type methodology is used to determine the benefits of a remedial treatment. In this methodology, costs of crashes and predicted treatment effects are defined in terms of crash types. The only inclusion of a severity value is with each crash type having two cost values, one where the speed limit is less than 80 km/h, and a higher value where the speed limit is 80 km/h or more. It is felt that these current crash values have shortcomings as they place too much emphasis on projects that prevent crashes of likely low severity. Data are readily available for factors that can predict the likely severity of reported crashes and the aim of this research was to examine and use these factors to better define categories of crashes and their values. This was found to have practical implications for improving the prioritisation of road safety crash reduction programs. Categories of crashes were identified, based on differences in average severity and their relevance to possible treatments. The analysis demonstrates the higher priority of projects that address more severe crashes when crash values are determined using:

- RUM codes rather than DCA codes to include run-off-road on bend crash type codes that indicate the side of the road which the vehicle went off
- three speed limit groups rather than two
- darkness as against daylight
- the area of the State where the crashes are located
- whether the crash happened at an intersection or on a Freeway/Motorway
- different types of safety barrier
- size of curve radius.

Cost benefit analysis and crash types

NSW and Federal black spot proposals are currently assessed by cost-benefit analysis (CBA). The State Black Spot Program has a minimum bench mark Benefit Cost Ratio (BCR) of 3.0 with further prioritisation using the number of fatal and injury crashes at the site. The Federal Black Spot program must have three injury crashes at the site in the most recent five years with prioritisation by BCR value and cost. However the injury crashes that have occurred at these sites may be of a low severity and the main criterion for prioritisation is the benefit–cost ratio. The CBA methodology is explained in federal (AusLink 2006) and NSW (RTA 2006) documentation.

In NSW there is no distinction in the Police crash data of injury severity as the data only states if a crash was a fatal, injury or towaway crash. Injury crashes are not broken down into serious, hospitalised or minor and therefore it has been difficult to determine better crash cost values. Self reported property damage only (PDO) crashes are also not included in the database.

In Cost Benefit Analysis, the estimated benefits depend on the crashes expected to be prevented by the proposed work. This obviously requires crashes to be assigned a cost value and the method of valuing the cost is based on determining the severity of each crash type. (Examples of crash types are head on, rear end, pedestrian crossing the road etc.)

The method of valuing crashes by crash types was developed by Andreassen. Andreassen (1992, page 1), argued that some crash types are inherently more severe in terms of probability of death or injury, and therefore an analysis that uses all recorded crashes, with no breakdown into severities will reflect the distribution of severity over crash types. The basic proposition is that the types of crashes that have happened at a location provide a prediction of the types, and thus the expected severities, at the location.

Speed is also a major determiner of crash severity. Speed limit was used as a determiner of expected crash value, as well as crash type, in Andreassen's original work. The present NSW method currently in use only has two speed zone variables by setting a higher severity value for a crash type where the speed zoning is 80 km/h or greater (100km/h & 110km/h) compared with the value where the speed zoning is less than 80 km/h (70km/h, 60km/h etc.).

The crash-type method also provides a meaningful approach to predicting the effects of the proposed works. Each type of work (called a "countermeasure treatment type") is associated with a proportional reduction (or increase) in crashes of particular types. For example, according to the AusLink table (2006, pages 21 and 22), improving superelevation on a curve is estimated to reduce head –on crashes (by 50%), off-road-on-curve crashes (by 80%) and rollover–on-curve crashes (by 80%), with no effect on other types of crashes that happen at the site.

In the CBA, the estimated annual project benefit is the difference between

- the sum of values of the crash types expected at the site if untreated, and
- the sum of values after reducing the numbers of crashes in each type by a proportion relating to the proposed countermeasure treatment type.

Purpose of this work

The main problem with the current method of calculating BCRs is that it does not provide sufficient focus on the prevention of fatal and serious injury crashes.

The work described in this paper is intended to improve the current CBA method, while retaining its major features. The CBA method benefits road safety to the extent that it results in a selection of projects that prevent most fatalities and other serious injuries. Large safety benefits can be gained from improving the method without necessarily trying to achieve absolute accuracy.

Imagine, for example, two intersections that have the same speed limit (say 60 km/h) and the same crash types. They are dissimilar because traffic flows freely at one while the other is chronically congested. The one with dense traffic is likely to have many more crashes but because of the low speeds, crashes in dense traffic are much less severe on average. Under the current CBA method, the intersection with greater traffic density would have higher priority for work. Such cases are common, and can often result in the focus of road safety resource usage shifting away from prevention of serious trauma.

The improvements to the CBA method, described below, bases values of crash types on factors that provide better association with crash severity.

A study was undertaken to determine factors that affect crash severity, and therefore value.

Method

The Cost Benefit Analysis (CBA) method has to be easy to use correctly. The factors included have to be understandable and meaningful. Ease of use means that relevant data should be readily available. Therefore, the factors were defined in terms of the crash data.

Initially, 1995 to 2005 data were used however the values reported in examples below are based on analysis of 1997 to 2006 NSW crash data.

The body of knowledge does not exist from which a complete regression model could be developed. Therefore, a hierarchical analysis was undertaken. This hierarchical process began with a grouping of crash types (defined in terms of Road User Movements - RUMs). RUMs were grouped in similar crash types and considered in relation to similar severities. This resulted in RUMs being grouped in a similar way to the current DCA groupings of crash types. Why RUM codes and not DCA codes have been used is explained in the next section.

The factors considered are described in the following sections of this paper.

Severity was analysed via fatalities per reported crash.

Fatalities per reported crash type give a better indication of the overall crash severity of that crash type. Fatalities per reported crash more directly addresses the safety objectives of the Safe Systems approach to road safety of fatal and serious injury prevention and amelioration rather than just crash prevention per se. They result in greater severity differences between crash categories, because (except for pedestrian crashes) there is a positive correlation across crash categories between the number of fatal crashes per reported crash and the number of fatalities per fatal crash. Fatal crashes per reported crash was considered as an alternative to fatalities per reported crash however this was discarded because it was felt that fatalities per reported crash gave a better indication of overall crash severity.

Each group was broken down (that is, divided into sub-groups) by the factor that had the largest effect on fatalities per reported crash. Then each sub-group was analysed to see which of the remaining factors had the largest effect. Each sub-group was broken down by this factor to form a sub-sub-group, and so on. This process was stopped when no variables remained or when no remaining variable had a statistically significant effect. The statistical process was modified by some judgement to remove anomalies and to ensure that the results were as meaningful and practical as possible.

As an example of the hierarchical process, one crash category is head-on (RUMs 20 or 50), in a speed zone of 60 km/h or lower, in the dark, not at an intersection, in inner Sydney. This category is generated from a first break down of the crash type into speed zone groups, because speed zone had the strongest effect, then by whether the crash happened in the dark, which had the strongest effect for crashes in a speed zone of 60 km/h or lower, and then by whether the crash happened at an intersection, and then by the area of the State where the crash happened. Each breakdown results, of course, in at least two paths leading to crash categories. Head-on crashes, for example, were divided into 12 categories. The method has the desirable implications that a crash type will be divided into more categories, the greater the frequency of its occurrence, the greater the number of resulting fatalities, and the greater the variation in severity related to the factors examined.

After the categories were defined, it was necessary to assign a dollar value to each, in order to use these in CBA calculations. The categories differ in terms of the number of fatalities per reported crash in the category. These categories should also differ in the proportion of injuries that are serious rather than non-serious. But the RTA's crash database does not distinguish between the severities of non-fatal injuries. Old data, reported by Andreassen (1992) were used to estimate a relationship between fatalities per reported crash in a category and the proportion of injuries that are serious.

The costs of fatalities and injuries per reported crash in each category were then based on NSW RTA values for these casualty severities. These values are based on Austroads (2003), indexed to December 2005 by using average weekly earnings (from Australian Bureau of Statistics).

Crash type using RUM code rather than DCA

The current NSW and AusLink CBA method defines crash types by DCA codes. According to AusLink (2006, page 22), DCA codes were devised by Andreassen (1983). According to the Bureau of Transport Economics (2001, page 63) the "DCA code's predecessor" was the RUM code.

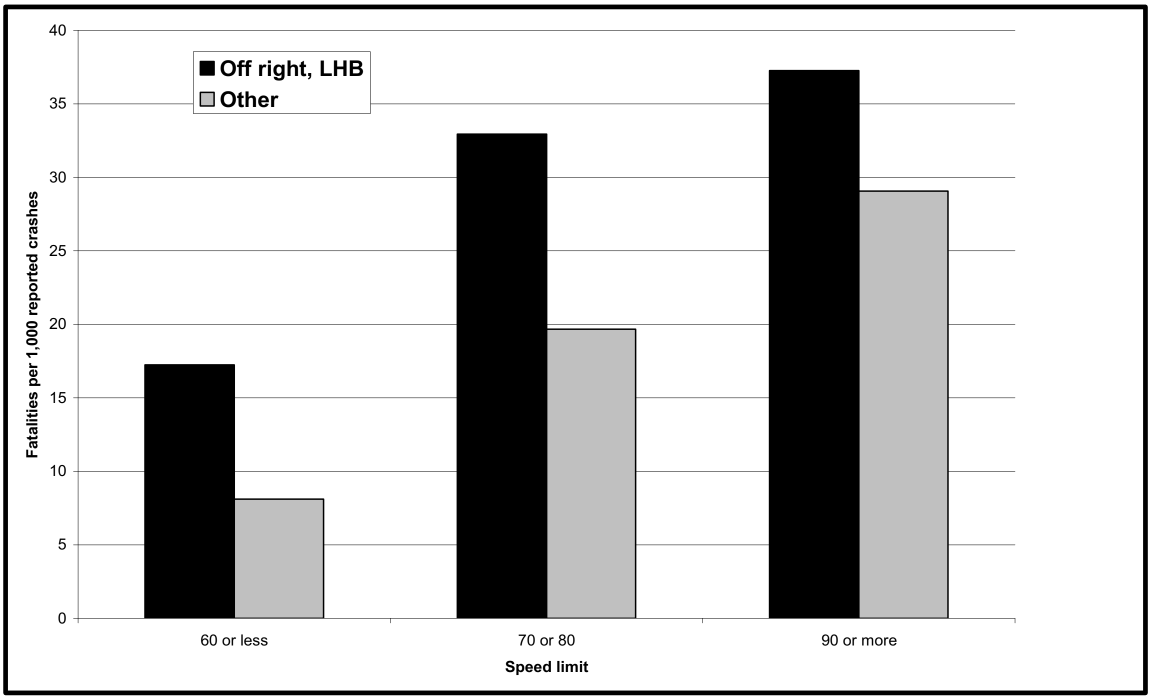

Figure1. Number of fatalities per 1,000 reported crashes in off-road-into object crashes comparing off road to the right on a left hand bend with others at different speed limits (NSW, 1997-2006, excluding freeways & motorways)

RUM codes are the primary code for crash types in NSW (but they can be translated to DCAs). RUM and DCA codes are very similar. For assessing severity factors RUMs had an advantage for single vehicle off-road-on-bend crashes. DCAs specify the direction of the bend. RUMs specify the direction of the bend but also specify the side of the road that the vehicle left, and the relationship between the two was found to be related to crash severity. The combination of a left-hand bend with a vehicle leaving the road to the right results in a reported crash being more severe (on average) than other reported off-road-on-bend-crashes; see ***Figure 1***.

Speed Zones

The current method distinguishes crash values based on whether the speed zone is

- 70 km/h or lower
- 80 km/h or higher.

The new study used three speed zone groupings:

- 60 km/h or lower
- 70 or 80 km/h
- 90 km/h or higher.

Consideration was given to breaking speed zones down further, particularly in the lower speed zones. But zoning (particularly 50 km/h) has been changing substantially over the relevant years, and it is likely that the changes are related to other aspects of the site, impossible to separate in this type of analysis. Perhaps, in future, a further speed zone breakdown would be useful.

The crash costs shown in ***Table 1*** reflect the large variation in the severity of a U-Turn crash depending on the speed zone. Many other crash types are similarly affected by speed zoning.

Table 1. Example of crash cost variations due to variations in speed zone of the crash site

Speed Zone	RUM Code	Crash Type	Crash Cost ($)
≤ 60-km/h	40	U - Turn	40,000
70 or 80-km/h	40	U - Turn	74,000
≥ 90-km/h	40	U - Turn	173,000
Crash costs based on current updated Human Capital Values, from Austroads (2003)			

After RUM groups were defined, the division into three speed-zoning groups was consistently the strongest determiner of value.

Darkness

Reported crashes are more serious (on average) if the crash happens in darkness.

There is usually less traffic on the road network late at night and this leads to higher travel speeds as well as larger numbers of fatigue crashes, alcohol related crashes, speeding crashes and driver behaviour crashes. All of these factors can increase crash severity, however darkness was considered to be the common denominator.

However darkness did not affect the severity of right-angle crashes.

It particularly influenced the severity, and therefore the value, of head-on, off-road, and pedestrian crashes. The effect of darkness is shown in ***Figure 2***.

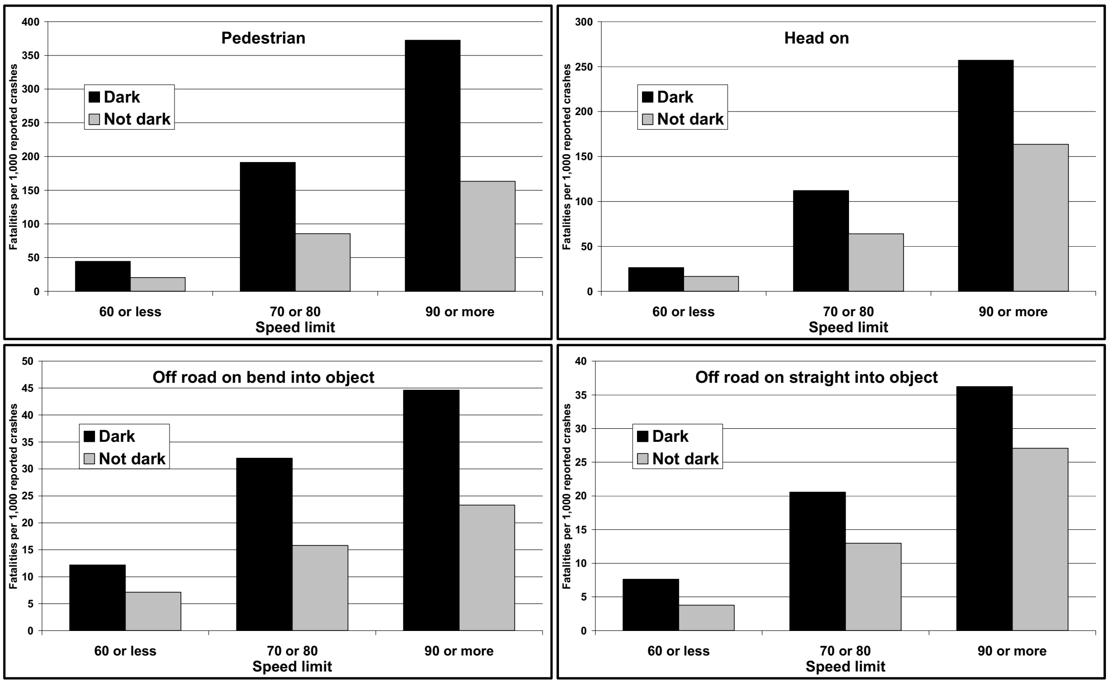

Figure2. Number of fatalities per 1,000 reported crashes in pedestrian, head-on, off road on bend into object, and off road on straight into object crashes by natural lighting (NSW, 1997-2006)

Table 2 shows the cost variation that light and dark has on pedestrian crashes. It also shows the difference in severity if the crash occurs at an intersection. High-speed pedestrian crashes at intersections are very rare, and a separate value was not able to be determined (nor would it be of practical value).

Table 2. Example of crash cost variations generated by dark and light as well as at an intersection or not at an intersection

Speed Zone	RUM Code	Crash Type	Light-Intersection	Dark-Intersection	Light-Non Intersection	Dark-Non Intersection
≤ 60-km/h	00-09	Pedestrian	$155,000	$186,000	$168,000	$297,000
70 or 80-km/h	00-09	Pedestrian	$213,000	$382,000	$368,000	$561,000
≥ 90-km/h	00-09	Pedestrian	$454,000	$759,000	$454,000	$759,000
Crash costs based on current updated Human Capital Values, from Austroads (2003)						

Area of the State

The reported crashes in some areas of NSW are more severe, even after correcting for crash type and speed limit.

The State was divided into six areas, broadly related to distance from the centre of Sydney. The areas were:

- Sydney City and South Sydney (CBD and close surrounds)
- Other inner Sydney
- Outer Sydney
- Sydney surrounds
- Elsewhere (east of Great Divide)
- Elsewhere (west of Great Divide).

Each Local Government Area has been designated with an area number from 1 to 6 which reflects the severity of the crashes that occur in it.

SPEED ZONE	RUM CODE	CRASH TYPE	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
60KPH OR LESS	74	OUT OF CONTROL ON STRAIGHT (ROLLOVER)	64,000	64,000	92,000	97,000	97,000	97,000
70KPH TO 80KPH	74	OUT OF CONTROL ON STRAIGHT (ROLLOVER)	64,000	64,000	92,000	122,000	122,000	122,000
90KPH OR GREATER	74	OUT OF CONTROL ON STRAIGHT (ROLLOVER)	64,000	64,000	92,000	137,000	195,000	195,000

Table 3. Example of crash cost variations of *out of control on straight (rollover)* crashes generated by the location in NSW of the crash site.

This Area factor had the effect of influencing the severity and value of nearly all types of crashes.

Intersection

Reported head-on, pedestrian and rollover on bend crashes were likely to be less severe if they happened at an intersection. Although intersection crashes are more common in lower speed limits, this effect still applied after allowing for speed limit.

An exception was pedestrian crashes in and around the Sydney CBD (Area 1 above) where pedestrian crashes were more severe if they happened at intersections.

Roundabouts

Crashes at roundabouts are unlikely to be severe. The effect was substantial enough to be used in assessing the value of the adjacent-direction crash category.

Expressway motorway

In Sydney and its surrounds, a substantial proportion of high-speed zone, off-road crashes were on freeways or motorways. Reported off-road crashes on expressways and motorways are less severe and of lesser value than off-road crashes on other high-speed roads. One of the reasons for the lower severity is that, if a vehicle hits an object off-road from an expressway, the object is very likely to be an appropriate safety barrier. Although expressways and motorways are unlikely to be proposed for black spot treatment, there is a need to separate them. If these were not separated, it would lead to an anomalous low value for similar crash types occurring on other high speed roads in and around Sydney.

Wet or dry road surface

Studies show that when roads are wet the number of reported crashes increases but the average severity of those crashes reduces (see, for example, Edwards 1998). This might be because drivers actually drive slower in wet weather and even though they may have more crashes they could be of a less severe type at a slower speed.

Consistent with previous study findings, this study also found that reported crashes were less severe when roads were wet. This applied to all crash types, except pedestrian crashes, whose severity was unaffected by whether the road was wet or dry.

Therefore if two sites have the same number of crashes, the same types of crashes and the same speed limit and so on, but one site has some of its crashes on a wet road, there is no clear implication for safety if this site is given less priority for treatment.

It is difficult to defend the inclusion of a dry (or wet) road surface factor in the analysis if we cannot substantiate any speculation about its implications for site selection for road safety work. Although a wet road surface may lead to more crashes, the actual severity of those crashes is less than on a dry surface therefore it was decided not to include a wet road factor in the analyses. The only way it could be included is if it was used as a cost reducing factor in the CBA calculations, however the differences were found to be marginal and would probably make little change to the outcome.

Other factors

Other factors will influence crash severity, but were not included directly in the crash data studies. The two additional factors that were considered were the type of safety barrier and the size of the curve radius. These are relevant to proposals to install or change safety barrier or to change horizontal alignment. These are discussed briefly below.

Type of safety barrier

The current value of safety barriers does not distinguish between different types of barrier in use therefore the crash frequency reduction approach to CBA is insufficient to capture this difference.

When a safety barrier is installed or changed, the number of reported crashes may or may not be reduced for various reasons. However the main purpose of a safety barrier is to reduce crash severity by changing the crash outcome rather than to prevent actual crashes. Therefore, it is necessary to make an estimate of the change in value of off-road-into-object crashes relating to barriers.

Information on the different types of barrier hit in a crash is not readily available from the current crash data. Nevertheless, in the description of their proposed projects, proponents would be required to describe what barrier, if any, is in place, and what type they propose to install.

Preliminary studies undertaken by the NSW Centre for Road Safety show a lesser severity for crashes into wire rope as against those into steel or concrete barrier. It appears a crash into wire rope should have a much lower expected severity value. Current research estimates the severity value of a crash into wire rope to be a half to a third of the value of a crash into steel or concrete barrier. This is significant enough to include type of safety barrier as a determining severity factor in the economic calculations.

Curve radius

The effect of curve radius on crash severity has also been studied in separate research undertaken at the NSW Centre for Road Safety. This research indicates that increasing curve radius, within particular ranges, can reduce crash likelihood but may also increase the expected severity of crashes that do occur (presumably because the crashes happen at a higher average speed). It also shows that where crashes occur on curves of different radius that crash frequency does not always correlate with crash severity. The expected changes in severity imply differences in crash value depending on curve radius.

Proposals to change alignment will be assessed in terms of the expected change in crash severity using the crash severity factors as well as the change in crash frequency using the crash treatment reduction matrix.

Conclusions

The findings from this study have shown that a number of varying factors such as speed zone, crash location, dark or light, type of road or intersection layout, size of curve radii and type of safety barrier all have a major impact on the severity of crashes. It has also shown that these factors can be calibrated so that they can be included in economic and safety impact evaluations. Further refinement of some of the factors may be undertaken in the future i.e. by calculating severity factors for each individual speed zone as there are still big variations in severity between some of the grouped speeds.

The detailed results are extensive, and unsuitable for presentation here. Nevertheless, the change in emphasis can be demonstrated by some examples.

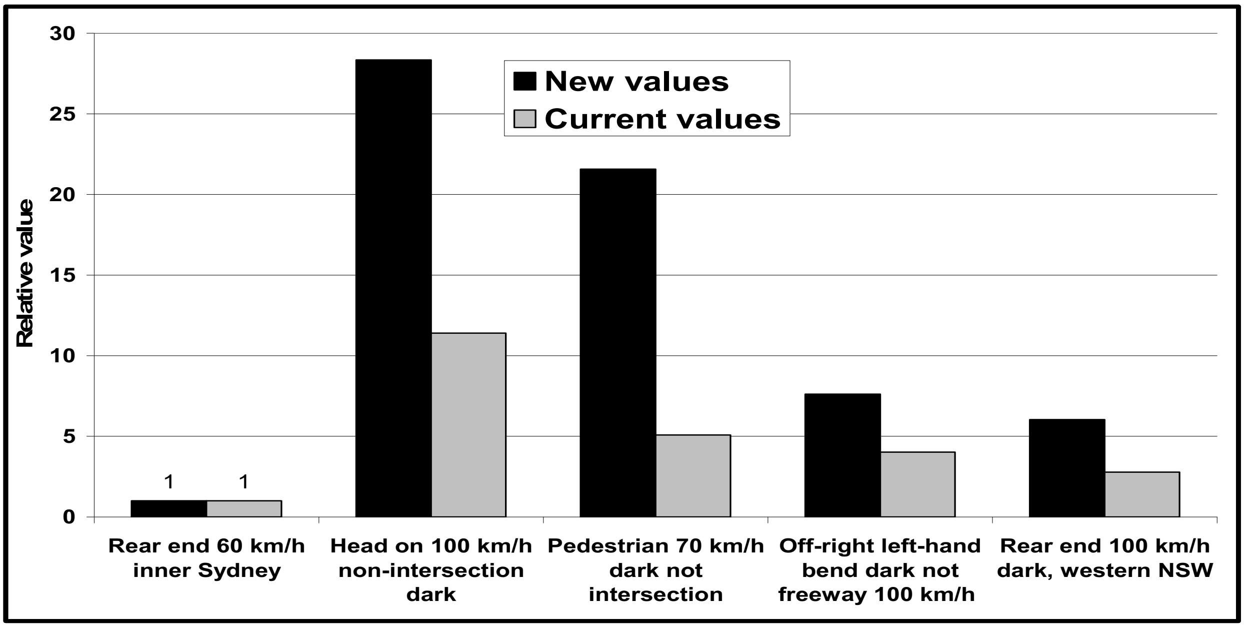

Figure3. Values of several crash categories relative to the value of inner Sydney rear end crashes, comparing current values with the values generated in this research

In inner Sydney rear end crashes, where the speed limit is 60 km/h or lower, are very common and comprise 5% of all NSW crashes. However these types of crashes are unlikely to be severe. ***Figure 3*** compares the values of several crash categories, likely to be severe, with this common crash type. The values used in the comparisons are those that the RTA currently uses (based on Andreassen's work) and the new values generated by the research described above. It can be seen that the new values are relatively much greater for these serious crashes, and therefore will result in higher priority (on average) for sites where crashes have occurred with factors likely to result in greater severity.

This approach is currently being extended to apply to the assessment of the expected road safety impact of proposed road maintenance, traffic and minor capital works projects. However it can't be applied to major road construction projects as it could not be expected that the crashes that may occur after the works are completed would fall in the same categories as those that occurred before the work was done.

Other jurisdictions may be able to use this methodology as well as some of the severity factors as there may be little difference from State to State, however composition of their crash database may make this difficult and the distribution of the Area factors would still need to be recalibrated for each State.

By creating a hybrid model that incorporates both the crash by type and crash by severity methodologies and by using a broader range of factors to determine expected crash severity and crash costs it is expected that road safety resources will be better targeted towards the prevention of death and serious injury to further reduce the rural road toll in NSW.

References

Andreassen D (1983) Standard accident definitions: primary accident classes and accident types *Australian Road Research*, 13[1], pp 10-24

Andreassen D (1992) *Costs for accident-types and casualty classes* Australian Road Research Board Research Report ARR No 227

AusLink (2006) *Black Spot Projects: Notes on Administration,* Australian Department of Infrastructure, Transport, Regional Development and Local Government (URL: http://www.auslink.gov.au)

Austroads (2003) Economic evaluation of road investment proposals: improved methods for estimating Australian unit crash cost Austroads, Sydney

Bureau of Transport Economics (2001) The black spot program 1996-2002: an evaluation of the first three years The Bureau, Canberra

Edwards J B (1998) The relationship between road accident severity and recorded weather Journal *of Safety Research* 29, pp 249-269

RTA (2006) *Road safety benefit-cost analysis: materials for program submissions* Road Environment Safety Update Number 26 (URL: http://whome.rta.nsw.gov.au)