Guidelines for Retro-fitting Existing Roads to Optimise Safety Benefits.
A Practitioners Experience and Assessment of Options for Improvement.

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Abstract

Crash data shows a consistently high level of run-off-the-road type crashes on high speed, undivided roads (90 kmh and greater) in New South Wales. There has been an annual average of 3,230 of these crashes on this road type between 1998 and 2003. The result is a total annual average cost of fatal and injury crashes to the community of more than $360 million (human capital cost values). The NSW Roads & Traffic Authority is committed to reducing the number and severity of vehicle crashes by ensuring a safe driving environment. This includes ensuring road designs for curve radii are compatible with a safe systems approach to road safety.

The RTA implements strategies to reduce the number of crashes when designing new alignments and upgrading existing alignments. Options to reduce crashes include reducing speed limits; widening and sealing the shoulder; removing roadside hazards; installing profile edge-line marking; installing advisory curve speed warning signs and installing curve alignment markers. More expensive solutions include increasing super-elevation on sealed shoulders where possible; removing roadside hazards at run-off areas and levelling of batter slopes to at least 4:1 or installation of an appropriate safety barrier where a run-off area is not available.

Application of research findings to focussed allocation of available funds can and has resulted in significant reductions in road trauma in NSW.

Keywords

Rural Road Safety, Curves, Shoulders, Clear Zones, Centrelines, Countermeasures

1 INTRODUCTION

The application of "greenfield" design standards when upgrading many lower class existing rural roads is often financially, physically or environmentally unachievable. This leaves the application of "non-greenfield" otherwise known as "brownfield" design standards as the only way that these roads can be made safer. Those sections of the existing rural road network that are exhibiting poor safety performance and where the "do nothing" option is not ethically appropriate can be improved by applying "brownfield" design standards. The NSW Centre for Road Safety - Safer Roads Research Section has undertaken a number of primary research projects as well as looked at a broad range of external research to determine at what point various incremental safety applications will maximise safety outcomes yet minimise the cost and/or environmental impact of the works.

2 WHAT IS INCREMENTAL SAFETY?

Long term crash analysis undertaken in Safer Roads Research Section indicates that maintaining existing two lane rural roads by only resealing or rehabilitating the pavement without also improving the unsafe formation can actually make the roads less safe for a number of years after the work is completed. This could be because reseals make the existing alignment look safer which leads drivers to drive them at higher speeds than before the reseal was undertaken. This in turn may lead to more severe off road into object crashes. Crash analysis undertaken in Safer Roads Research Section shows that resealing and rehabilitating pavements will have an effect on reducing single vehicle wet surface crashes, however these benefits are outweighed by the actual increase in dry surface crashes generated for a number of years after implementation. This suggests that unless additional incremental safety treatments are retro-fitted to the road formation when resealing or rehabilitating pavements, then these roads will continue to exhibit poor safety performance.

However, this does not mean that there is nothing that can or should be done to improve the safety performance of these roads. There are incremental levels of improvement available that can be retro-fitted to existing roads that will greatly increase their safety performance at reasonable costs.

3 COUNTERMEASURES AVAILABLE

These countermeasures apply mainly to rural high speed and rural/urban mid speed roads and are not usually applicable to urban lower speed environments. In NSW the existing rural local unclassified road network has shown little reduction in serious crashes over recent years compared to the large reduction that has occurred in urban areas of the State. Applying appropriate safety measures to these

roads must be of the highest priority when looking at ways to reduce the NSW road toll.

Some examples of incremental safety applications that are available to practitioners are described below:

3.1.0 Dangerous Curves

Internal crash analysis undertaken in Safer Roads Research showed the smaller the radius on a high speed road the higher number of crashes. However, the speed of the vehicle through the curve will usually determine the severity of any crash that may occur and in most cases smaller curves are more likely to have lower speed crashes. That is why crashes on curves of 200 metres or less in radius, are usually of a lesser severity than those on larger, high speed curves. A Safer Roads Research study *(Ref.1)* into crashes on curves located 6,950 single vehicle crashes that had occurred on rural undivided high speed State roads (Figure 1).

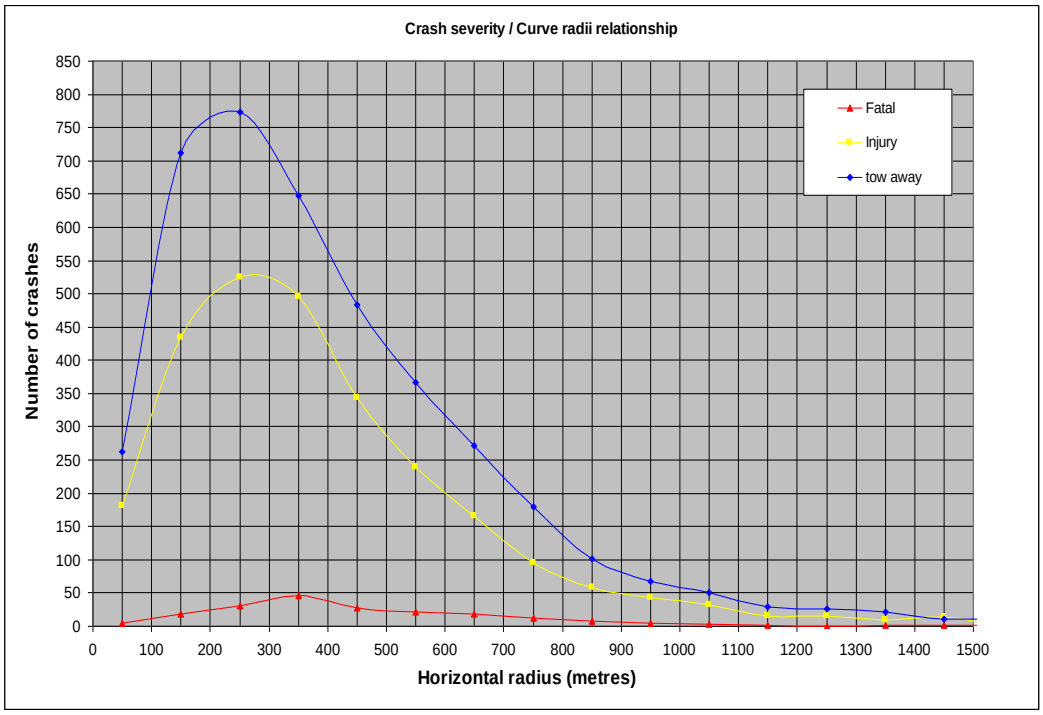

Figure 1 - Graph Showing the Relationship between Curve Radii and Crash Severity

(Internal Safer Roads Research Study - 2006)

This study looked at both the severity of the crash and the size of the curve radius with the findings indicating that the more serious crashes occurred on curves with radii ranging from 200 metres to 600 metres. Fatal crashes peaked at around radius 350 metres with injury crashes peaking around 275 metres radius and towaway

crashes peaking at around 200 metres radius. When the graph was adjusted by the percentage of each of the curves sizes within the road network there was minimal variation in the outcome. The confidence percentage level for this data was in the high 90's.
These findings validate the current RTA Road Design Guide's *"grey area"* of curve radii, *(Ref. 2)* however the inclusion of serious crash severity has extended this area from the current 300m - 440m radius non-use area to 200m - 600m radius.

3.1.1 Priority 1 Curves – 200 metre radius to 600 metre radius.

These curves make up approximately 10% of the total NSW State road network and generate the highest number of severe crashes. These curves often appear to drivers to be able to be negotiated at high speed however there is little room for error and the resulting crashes occur at speeds that lead to higher crash severity (see Image 1). The Safe Systems approach to road safety identifies the reduction of fatal and serious injury crashes as its main priority and this range of curves generates the highest number of serious crashes.

Image1 - Typical 300 metres radius curve on a two lane rural road

The types of treatments that can be used should look at reducing both the occurrence of the crash as well as the severity of the crash.

3.1.2 Priority 2 Curves - 50 metre radius to 200 metre radius.

These curves make up only approximately 3% of the NSW State road network yet generate the highest number of crashes. However the crashes that do occur tend to have a lesser severity. These types of curves are usually harder to eliminate as they tend to occur on roads through difficult terrain where improvement to the alignment is often impossible to achieve (see Image 2).
The type of treatments used on these curves should look at reducing mainly the occurrence of the crash on the smaller curves (50m to 100m radius) but both the severity and the occurrence on the larger curves (150m to 200m radius).

Image 2 - Typical 150 metres radius curve on a two lane rural road – Note the Curve Alignment Markers

3.1.3 Priority 3 Curves – 600 metre radius to 1000 metre radius.

These curves make up approximately 8% of the total NSW State road network. The speed of the vehicle through these curves has a big impact on the severity of any crashes that may occur on them but in most cases the radius of the curve is not always considered to be the primary contributing factor in initiating the crash.

Image 3 - Typical 800 metre radius curve on a two lane rural road

Treatments used to address crashes on these curves should look at reducing the severity of the crash only.

The following treatment options have been shown over a long time to help reduce the specific crash types being targeted on rural roads. The RTA's new :

* widen and seal shoulders from the Start of Superelevation transition (SS) through to 1.5 metres at the Tangent/Spiral (TS) then to 2.5 metres at the Spiral/Circular Curve (SC) and carry this width through the curve and then transition back to the SS. *NB: Where these shoulder widths are unattainable due to terrain constraints then they should be the best that can be achieved under the circumstances.*

* install profile edge-line marking from the entering SS to the finish of the departure SS transition

* install advisory curve speed warning signs where appropriate

* install Curve Alignment Markers (CAMS)

* remove roadside hazards where a run-off area of at least 10 metres is available at the back of the curve and level out batter slopes to 6:1 with a minimum of 4:1.

* install wire rope safety barrier where a run-off area is not available.

* Separate opposing flows with a wide tactile centreline of up to 1 metre in width wherever possible. (1.2 metres if a wire rope safety barrier is to be installed.)

* increase super-elevation on sealed shoulders through the curve from SC to SC where possible

Any of these remedial treatments can be used in isolation or combination to make dangerous curves safer. *NB: Where the curve arc length is less than 300 metres then the 2.5 metre widening and some of the other remedial treatments should be extended to ensure that errant vehicles are captured by the proposed treatments.*

3.2.0 Shoulder Width

Any width of shoulder sealing where there currently is none will generate very good safety benefits. Shoulder seal width can be varied according to whether it is on a straight section or a curved section of road. Wide sealed shoulders up to 3 metres in width provide much better safety value when applied to the outside of curved sections of road.

3.2.1 Straights

The types of crashes that occur on straight sections of alignment tend to be different to those that occur on bends. They are much more likely to have a distraction or fatigue component than those on curves. Only 40% of all *loss of control* crashes on rural roads in NSW occurred on straights even though straights and curves larger than 3000 metres in radius make up 67% of the NSW State road network.

The Safer Roads Research study that led to the development of Asymmetrical Design Principles *(Ref. 3)* showed that these crashes could be reduced by up to 25% to 38% with the implementation of sealed shoulder widths of only 0.5 metres to 1.0 on straight sections of alignment.

Sealed shoulder widths of 2 and 3 metres will always give better total safety outcomes than smaller sealed shoulder widths however the incremental benefits fall quickly away between 1.0 and 1.5 metres on straights and safety value for money is maximised at about 1 metre in width.

3.2.2 Curves

The types of crashes that occur on bends are much more likely to be related to the speed of the vehicle entering into the curve. Distraction and fatigue crashes do occur on bends however, most loss of control crashes on bends are due to excessive speed for that size of curve radius. This also applies to the 50% of all *head on not overtaking* crashes that occur on curves with vehicles cutting right hand bends or drifting wide on left hand bends due to excessive speed.

The Asymmetrical Design study *(Ref. 3)* also showed that widening the outside shoulder seal of curves by up to 2.5 metres without widening on the inside of the curve could have an effect in reducing up to 51% of loss of control crashes. This is because up to 60% of *loss of control* crashes on rural roads occurred on curved sections of alignment and widening the outside sealed shoulder could have an affect in reducing up to 85% of these crashes.

3.3.0 Clear Zone Width

Current RTA "greenfield" design standards for clear zones on high speed roads of 10 to 12 metres *(Ref. 2)* are not achievable on most existing rural roads due to current NSW environmental legislative restrictions. A Safer Roads Research study of *run off road crashes into objects* on undivided rural roads *(Ref. 4)* showed that there are good safety benefits to be gained in trying to achieve a clear zone width of at least 5 metres wherever possible.

According to AASHTO's Roadside Design Guide (1996) *(Ref. 5)* a 5m width of clear zone on 100km/h roads could reduce the risk of crashing into an object by over 50%. (see Figure 2)

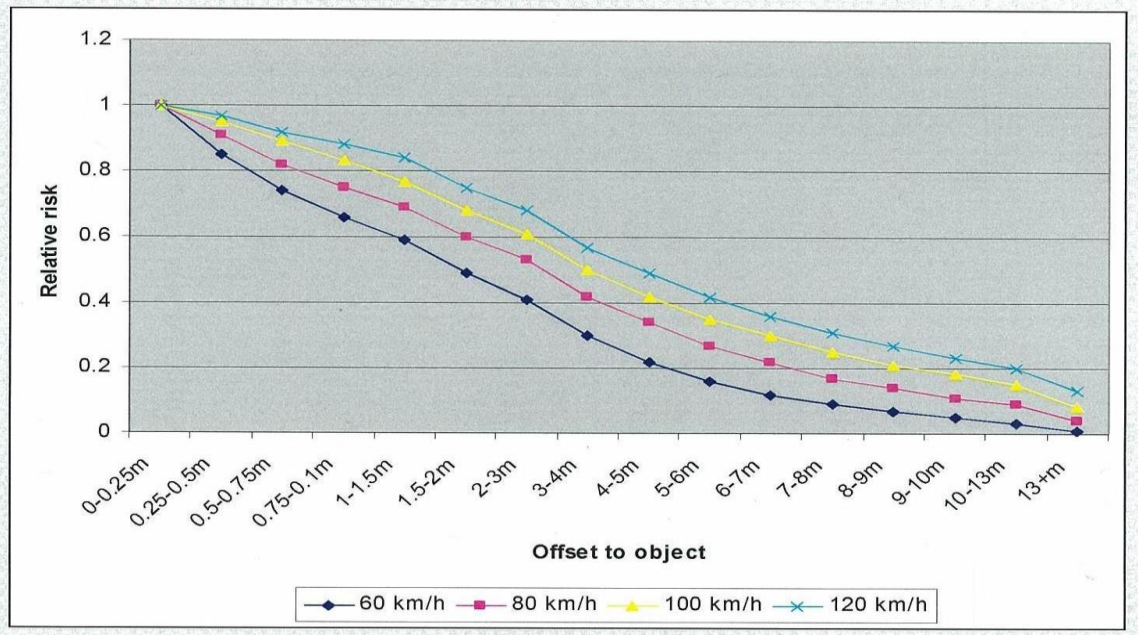

Figure 2 - Clear Zone Crash Risk - Various Speed Zones

(AASHTO Roadside Design Guide -1996)

These outcomes correlate closely with the Safer Roads Research study into run off road into tree crashes that showed that 5m to 6m clear zones could be expected to reduce crash severity as well as crash occurrence.

3.4.0 Centreline Width

Current standard centreline widths leave no room for error on the driver's part and only small lapses in concentration due to fatigue or distraction can lead to severe crashes. Crash analysis of variable width centrelines that have been installed on two lane rural sections of the Pacific Highway in NSW show that they have had an impact in reducing crossover type crashes such as *head on not overtaking* and *off to the right* crashes. Presently these centrelines act as a painted median which prohibits overtaking. Reductions in cross over crashes *(Ref. 6)* can be further enhanced if the centreline delineation is audio-tactile.

A new audio-tactile centreline configuration, up to 1.2 metres wide, will be trialled on the Newell Highway in NSW to see how drivers react to and accept this new configuration. The new centreline configuration will permit overtaking where it is considered to be safe and restrict it where it is not. It will be undertaken in 2009 along two 5 kilometre sections of road with a report being prepared once the pre and post evaluation has been completed.

Image 4 - Wide painted median, Pacific Highway south of Urunga (note old linemarking)

4 CONCLUSIONS

The NSW Roads & Traffic Authority's (RTA) Chief Executive released his "*Road Safety Challenge*" *(Ref. 7)* in 2007. It confirmed the introduction of the Safe Systems Partnership approach to road safety and its mainstreaming and integration into all areas of the RTA. It also stated that safety impacts would be assessed when developing a program of maintenance or reconstruction works on poorly performing sections of the existing road network.

Many existing rural and rural/urban state and local roads are still exhibiting high rates of fatalities and serious injuries and it is considered that these roads are where the next big reduction in the NSW road toll will need to be found. The long held view that the resealing or rehabilitation of a road pavement will make it safer has been shown in an internal unpublished Safer Roads Research study by Dr David Saffron to be only partially true for wet surface crashes and is without foundation for the majority of dry surface crashes. Maintaining the status quo will not make a road safer and in many cases could initially make it less safe.

Applying an incremental safety approach permits practitioners to selectively retro-fit effective interim safety improvements to those sections of the existing road network where the application of "greenfield" standards are constrained by terrain and/or environment and/or lack of funding. This application of incremental "brownfield" design standards will not only help to make the existing road network safer by providing practitioners with safer but less costly options to retro-fit, they will also allow for more of the network to be upgraded due to a more efficient use of road construction and maintenance funding.

Acknowledgements:
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