Applying Safety Countermeasures Incrementally to Existing Roads

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Abstract

It is recognised that the safety performance of existing roads can be improved without having to implement the standards used to design new roads. This paper explores the wide range of incremental options available to practitioners to apply incrementally to improve safety on existing roads. Incremental Safety is the application of non-greenfield design standards to sections of existing road where the road is exhibiting poor safety performance. Incremental Safety standards may be applied where the “do nothing” option is not ethically appropriate and the application of “greenfield” design standards is financially, physically or environmentally unachievable.

Incremental Safety Principles are proposed as a pragmatic and cost efficient means of improving the safety performance of the existing NSW road network. It is based on the premise that retro-fitting cost effective and appropriate safety improvements can generate good safety benefits when applied selectively to existing roads. Many existing rural and rural/urban state and local roads are still exhibiting high rates of fatalities and serious injuries and these roads provide the opportunity for significant reductions in the NSW road toll. The application of Incremental Safety Principles will help practitioners to make the existing road network safer by providing them with safe but less costly remedial options.

Introduction

Incremental Safety is the application of non-greenfield design standards to sections of existing road where the road is exhibiting poor safety performance and the “do nothing” option is not ethically appropriate and the application of “greenfield” design standards is financially, physically or environmentally unachievable. Safer Roads Branch has used a broad range of both internal and external research to determine at what point the value of various incremental safety applications maximise safety outcomes yet minimise the cost and/or environmental impact. They are proposed as a pragmatic and cost efficient means of improving the safety performance of the existing NSW road network and are based on the premise that retro-fitting small appropriate safety improvements can generate good safety benefits when applied effectively and selectively to existing roads.

Why Incremental Safety

Many existing highways as well as regional and local roads within the NSW rural road network fall below the current design standard that would apply for that road to function safely at its designated speed zoning. They were designed in the past to a standard that was applicable at the time but is now outdated. Speed zoning creep meant that the default speed zoning for rural roads changed from 50 mph (80 km/h) to 100 km/h in 1979 and they now function at higher speeds than they were originally designed. Economic evaluation, environmental legislation and limited funding levels have precluded many of these roads from being brought up to an appropriate “greenfield” design standard. Crash analysis studies undertaken in the NSW Centre for Road Safety show that maintaining these roads by only resealing or rehabilitating the pavement without also improving the road geometry may actually make the roads less safe for a number of years after the work. This may be due to these resealed sections being driven at higher speeds than before the reseal was undertaken which could in turn lead to more severe Off Road into Objects crashes. Crash analysis indicates that resealing and rehabilitating pavements will have an effect on reducing single vehicle wet surface crashes. However these benefits are outweighed by the actual severity increase in dry surface crashes generated for a number of years after implementation. This suggests that unless additional incremental safety treatments are installed when rescaling or rehabilitating pavements, 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.
Applications

RTA Applications
Crash studies have shown that rural roads exhibit high numbers of serious crashes because drivers often travel along rural roads at high speed even though the formation and alignment may be poor. It is envisaged that these sections of road will be prime candidates for the application of Incremental Safety Countermeasures.

Council Applications
Unclassified and Regional roads have shown no reduction in crash rates over the last 10 years and the limited finance available to Local Government means that there will be insufficient funding to upgrade these roads to a level that will help reduce the crashes that are currently occurring.

Options
These options mainly apply to rural high speed and some rural/urban mid speed roads and are not usually applicable to urban lower speed environments. Roads with the worst crash history should be considered to be of the highest priority. Conversely urban lower speed roads have been showing big gains in serious crash reduction since 2001 and continue to improve.

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

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 provide much better safety value when applied to the outside of curved sections of road (Levett 2005).

Shoulders on 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. Previous run off road crash studies showed that only 40% of all loss of control crashes on rural roads occurred on straights even though straights made the largest proportion of the rural road network. Straights and curves larger than 3000m in radius make up 67% of the State road network. The study that led to the development of Asymmetrical Design Principles showed that these crashes could be reduced by up to 38% with the implementation of sealed shoulder widths of up to 1.0m on straight sections of road.

Sealed shoulder widths of 2m and 3m will always give better total safety outcomes than smaller sealed shoulder widths. However the incremental benefits fall quickly away between 1.0m and 1.5m on straights and safety value for money is maximised at about 1m in width (Levett 2005).

Shoulders on Curves
The types of crashes that occur on bends are much more likely to be related to the speed of the vehicle entering the curve. Distraction and fatigue crashes do occur on bends however, most loss of control crashes on bends are due to excessive speed for the design of the curve. 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 (Levett 2005) 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 occur on curved sections of alignment and widening the outside sealed shoulder will have an affect on 85% of these crashes.

Speed Zoning
Where the alignment and the formation of the road cannot be made safer by physically improving the road then reducing the speed limit is a valid option available to all practitioners. The speed limit of a road should reflect the character and function of the road itself i.e. roads that can’t be safely driven at...
high speed should not be speed zoned as such. The RTA’s “NSW Speed Zoning Guidelines – Version 3.0” (2009) gives direction on how a road should be assessed to ensure the correct speed limit is applied. In these guidelines crash history is recognised as an important factor in setting speed limits.

**Rural Junctions**
The safety efficiency of rural junction design is currently under review (Tang 2009) with anecdotal evidence from Queensland and Victoria that the AUR (AUxiliary Right turn) layout is causing crash problems on roads with higher numbers of heavy vehicles. The RTA’s Pacific Highway Office has developed and installed a number of modified CHR (CHannelised Right turn) layouts (see Image 1) where pavement area was restricted. These modified CHRs only require the same amount of extra pavement as an AUR and can be fitted to T junctions where the volume of traffic using the junction is low.

![Image 1 - Modified CHR - T Junction Layout on the Pacific Highway at Shark Creek](image1.png)

Further crash analysis studies are currently being undertaken to demonstrate the road safety benefits of T junction layouts, however it would be prudent to investigate if a modified CHR layout could be installed before installing an AUR layout at any constricted site on the State Highway network.

**Batter Slopes**
The flattening of batter slopes on straights and on the outside of unsafe curves where an adequate clear zone is available can be expected to reduce the occurrence of run off road rollovers. This can be achieved by moving the table drain further away from the road and pushing the fill up to flatten the batter. Changing the fill slope from 2:1 to a minimum of 4:1 or a desirable 6:1 can have a big bearing on whether an out of control vehicle will roll or not. Having a clear zone on the back of a curve that is not traversable defeats the purpose of installing the clear zone as most vehicles will roll on a batter slope steeper than 3:1. Flattening batter slopes also reduces the high cost of installing unnecessary safety barriers.

**Audio-tactile Linemarking**
The safety benefits of audio-tactile line marking are well documented. It reduces run-off-road and head-on-not-overtaking crashes on the rural network by alerting distracted and/or inattentive errant drivers and allowing them to re-adjust their alignment. A recent study undertaken by the Injury Risk Management...
Research Centre at University of NSW and funded by the NSW Centre for Road Safety showed that installing audio-tactile edgelines and centrelines on undivided rural high speed roads gave a “significant decrease” in targeted crashes (Hatfield et al 2009). Anecdotal evidence from maintenance engineers on the Pacific Highway in NSW also indicates that where audio-tactile line marking is installed either side of wire rope median it greatly reduces the number of low severity hits on the wire rope thereby reducing maintenance costs.

The current environmental call for the removal of audio-tactile linemarking due to noise exposure will negate the purpose of its application to prevent serious off road crashes on rural roads. This may require a change in how and where audio-tactile linemarking is applied to reduce the chance of nuisance hits yet still maintain its safety effectiveness.

Clear zone Width

Current “greenfield” design standards for clear zones on high speed roads of 10m to 12m are not achievable on most existing rural roads due to environmental restrictions and costs. A Safer Roads study of run off road crashes into objects on undivided rural roads 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) a 5m width of clear zone on 100km/h roads could reduce the risk of crashing into an object by over 50%.

Figure 1 - Clear Zone Crash Risk - Various Speed Zones (AASHTO Roadside Design Guide 1996)

These outcomes correlate closely with the Safer Roads 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. New construction projects will still require 10m to 12m clear zones to be installed unless there no traversable run off area is available. In the case of no safe run off area, an appropriate safety barrier would need to be installed.

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 disastrous consequences. Crash analysis currently being undertaken of variable width centrelines that have been installed on the Pacific Highway (see Image 2) indicate that they have an impact in reducing crossover type crashes such as Head On – Not
Overtaking and Off to the Right crashes (Levett et al 2009). These centrelines act as a painted median which prohibits overtaking. Reductions in crossover crashes can be further enhanced if the centreline delineation is audio-tactile.

A new audio-tactile centreline configuration, 1.2m wide, will be trialled on the Newell Highway to see how drivers react to and accept this new type of separation. 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 sections of Highway that have an adequate pavement width of at least 11m to accommodate the wider centreline.

Safety Barriers
Two unpublished studies undertaken in the Safer Roads Branch Research Unit show that installing wire rope safety barrier (WRSB) may generate up to 65% less casualty crashes than by installing either steel w-beam or concrete safety barriers. The actual figures from these two studies were:

- **First case study (189 crashes)**
  - WRSB: 16% casualty crashes/km
  - Steel W-beam: 37% casualty crashes/km
  - Concrete: 35% casualty crashes/km

- **Second case study (293 crashes)**
  - WRSB: 11% casualty crashes/km
  - Steel W-beam: 39% casualty crashes/km
  - Concrete: 34% casualty crashes/km

These two studies showed that wire rope barrier was by far the safest barrier type for protecting vehicle occupants. These findings are consistent with crash reductions achieved on the Pacific Highway with WRSB medians (Levett et al 2009).

Post Colour
Wire rope safety barrier with white posts should be regarded as the default barrier to be installed in all cases unless a good argument can be made for installing some other type of barrier. Concrete or steel w-beam barriers should only be considered where wire rope would have too great a deflection and would not protect the hazard. The white posts greatly enhance the delineation of the road alignment and may actually reduce the occurrence of crashes while green posts tend to camouflage the barrier and would not. Yellow/orange posts should be used in snow areas.
At sites where no barriers have previously been installed due to lack of width on the edge of steep road edges or narrow bridges or culverts (see Image 3) it is suggested that wire rope safety barrier could be an alternative to the “do nothing” option. Recent testing of wire rope barrier on the edge of a drop-off shows that it functions effectively with the majority of vehicles using the road network. It is therefore proposed that if no other effective barrier type can be fitted then wire rope safety barrier should be considered as it will prevent the majority of vehicles from running over the edge.

Image 3 - Wire Rope Safety Barrier installed on the edge of Boree Creek Bridge on the Orange to Parkes Road (MR 61). The bridge previously had galvanised pipe railing.

The use of wire rope safety barrier in painted medians has also been shown to provide very good safety outcomes. Its selective use on the Pacific Highway (see Image 4) has reduced the number of serious cross-over crashes that had been occurring on undivided sections. A study by ARRB (McTeirnan 2009) suggests that although there was limited after data, its effects were still obvious with BCR’s of between 1.3 to 2.3. These benefits are expected to increase as more data becomes available.

A study by Carlsson (2009) looked at 5 years of before and after data on Sweden’s 2 + 1 Roads that have a 1.25m wide median wire rope barrier as well as lengths of roadside wire rope safety barrier. The study showed that fatal crashes were reduced by 76%. The study also indicated that motorcycle fatality risk on this type of road has been reduced by 40% to 50% over the time of the study.
Dangerous Curves
Crash analysis studies show that smaller radius curves have higher numbers of crashes. However, the speed of the vehicle through the curve usually determines the severity of any crash that may occur and smaller curves are more likely to have lower speed crashes. That is why crashes on curves of less than 200m in radius are usually of a lesser severity. A Safer Roads Branch Research study (Levett 2007) into crashes on curves located 6,950 single vehicle crashes that had occurred on rural undivided high speed State roads (see Figure 2).

![Figure 2 - Graph Showing the Relationship between Curve Radius to Crash Severity](image)

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 200m to 600m. Fatal
crashes peaked at around radius 350 metres with injury crashes peaking around 275m radius and towaway crashes peaking at around 200m radius. When the graph was adjusted by the percentage of each of the curve sizes on the road network there was minimal variation in the outcome. These findings validate the current RTA Road Design Guide’s “grey area” of curve radii, however the inclusion of serious crash severity should extended this area from the current 300m -440m radius no-go area to 200m – 600m radius.

**Priority 1 Curves – 200m radius to 600m radius.**
These curves make up approximately 10% of the total State road network and are considered to be the curves that have the most serious crashes (see Image 5). 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 usually result in high severity. 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.
Curves within the 200m to 600m radius range require additional works to protect road users and reduce their chances of both having a crash and the severity of that crash if they do have one.

![Image 5 - Typical 300m radius curve on a two lane rural road](image)

**Priority 2 Curves – 50m radius to 200m radius.**
These curves make up only approximately 3% of the total state road network yet generate the highest number of crashes although the crashes that occur tend to have a lesser severity (see Image 6). These types of curves are usually harder to eliminate as they tend to occur on roads through challenging terrain where improvements to the alignment are often difficult to achieve.
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 as speeds increase on the larger curves (150m to 200m radius) emphasis should move to both the severity of the crash and the number of crashes.
Priority 3 Curves – 600m radius to 1000m radius.
These curves make up approximately 8% of the total state road network. The speed of the vehicle through these curves (see Image 7) 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 considered to be a primary contributing factor in initiating the crash (Levett 2007).
Treatments used to address crashes on these curves should aim to reduce the severity of the crashes.
Possible options for treating curves are:
  * widen and seal shoulders from the Start of Superelevation transition (SS) through to 1.5m at the Tangent/Spiral (TS) then to 2.5m at the Spiral/Circular Curve (SC) and carry this width through the curve and then transition back to the SS.
  * 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 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 1.2m in width wherever possible. A width of 1.2m is required if there is the likelihood that a wire rope safety barrier may need to be installed later.
  * Install a wire rope safety barrier median.
  * increase super-elevation on sealed shoulders through the curve and then transition back to the SS.

Any of these remedial treatments can be used in isolation or combination to make dangerous curves safer.

**NB:** Where the arc length of the curve is less than 300m in length then the 2.5m shoulder seal widening and some of the other remedial treatments should be extended to ensure that errant vehicles are captured.

**Delineation**

Installing appropriate delineation is still the cheapest and best method of improving vehicle safety on rural roads. What may be completely visible by daylight may disappear when it becomes dark and vice versa (see Image 8) and drivers need to be made aware of approaching hazards so that they have time to take appropriate action to avoid any problems.

Delineation can take the form of painted pavement markings such as edgelines and centrelines that help define the alignment and the extremities of the road formation. It may also take the form of signs and structures such as Curve Speed Advisory signs, Curve Alignment Markers (CAMs) or white wire rope barrier posts that will give drivers an indication of changes to the road alignment (see Image 9).

**Image 8 – Standard yellow/black CAMs on curve are camouflaged by shadows from trees on the Oxley Highway west of Wauchope.**
The use of audio-tactile delineation is being questioned by some groups who consider it to be too noisy despite its well documented effect on reducing high severity distraction and fatigue crashes (Hatfield et al 2009). The way it is applied may require to be reviewed to ensure that it is still available to practitioners as a valid option for reducing serious crashes. This could be done by moving the tactile line outside the existing painted edgeline to reduce the incidence of vehicles inadvertently hitting the tactile line, thereby reducing the potential noise problem. It can often be difficult to strike a moral balance between environmental effects and saving lives however innovative changes in application should be explored to find a compromise that may address the concerns of both.

Conclusions

The RTA Chief Executive’s “Road Safety Challenge”, along with the introduction of the Safe Systems approach to Road Safety and its mainstreaming and integration into all areas of the RTA means that “do-nothing” should no longer be a viable option available to either maintenance or re-construction engineers when developing projects on sections of the existing road network that are exhibiting a poor safety performance. Many existing rural and rural/urban state and local roads are still have high rates of fatalities and serious injuries and these roads are where the next big reduction in the State’s road toll will need to found.

The long held view that resealing or rehabilitating a road pavement will make it safer has been shown to be only true for wet surface crashes and is without foundation for the majority of dry surface crashes where severity may increase. Maintaining the status quo will not make a road safer and in many cases could actually make it less safe.

Incremental Safety Countermeasures will permit practitioners to selectively retro-fit effective safety improvements to those sections of the existing road where the application of “brownfield” design standards are required and the application of “greenfield” standards is constrained by terrain and/or environment and/or lack of funding.

The pragmatic use of Incremental Safety Countermeasures 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 the better use of road construction funding.
References

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