

Understanding and Implementing Safe System Approach for Roads & Roadsides

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Abstract

New Zealand formally adopted the Safe System Approach in March 2010 with the Safer Journeys Road Safety Strategy to 2020. Since then we have been attempting to better understand the implications of this and how to turn strategy into action in respect to roads and roadsides activities in particular. This paper outlines our leanings to date through international advice, reviewing of relative research, modelling casualty outcomes of various safety programmes and countermeasures, development of the High Risk Rural Roads Guide (HRRRG) and High Risk Intersection Guide (HRIG), and the use of tools such as KiwiRAP¹, KAT and SafetyNET to inform road safety investments to create a more forgiving state highway road network, increasingly free of death and serious injury.

Key words: Safe System approach, Forgiving roads & roadsides, KiwiRAP

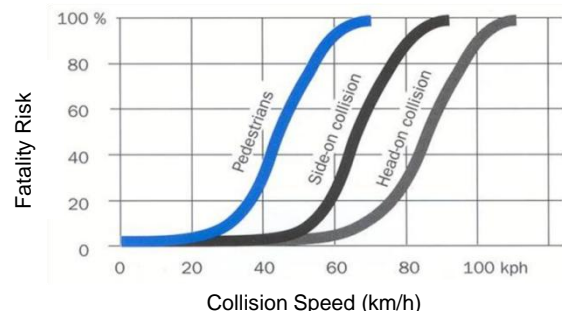
1. Safer Journeys and the Safe System Approach

Safer Journeys, NZ's Road Safety Strategy to 2010-2020 (MOT 2010) was released in March 2010. It introduced the concept of the Safe System approach. The Safe System approach has at its core the recognition that humans do and will continue to make errors while using the road system. It argues that these errors should not result in death and serious injury – a condition which requires that the road infrastructure, speeds and vehicles are designed and operated in a way to ensure that in the event of a crash, crash energies are kept below the thresholds likely to result in death and serious injury. Effectively this means either providing adequate protection of road users against high crash energies through vehicles and infrastructure or reducing impact and thus travel speeds.

Human tolerance to energy forces is best understood in the survivability speed graphs in Figure 1. The Safe System approach requires a fundamental cultural and ethical shift away from driver blame. Our understanding of what this really means and the effects on the way we do our business is still in its infancy.

Figure 1: Fatality Risk

Source: Supplied by Torsten Berg, Sweden



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2. New Zealand Road Casualty Problem

¹ KiwiRAP: New Zealand's joint agency Road Assessment Programme www.kiwirap.co.nz

Safer Journeys vision of “A safe road system increasing free of death and serious injury” focuses us on the higher severity fatal and serious crashes, and the requirement to consider casualty numbers as opposed to simply crash numbers.

Approx 40% of all deaths and seriously injured (DSi) casualties (2005-09) occur on the state highways which comprise only about 12% of NZ’s total road network. Of the state highway DSI’s, 84% occur on rural roads ($\geq 80\text{km/h}$), hence the focus on high risk rural state highways, through KiwiRAP (the NZ Road Assessment Programme), and the High Risk Rural Roads Guide. This differs from the local roads network where 64% of DSI’s occur on the urban network and fatal and serious (F + S) rural crashes are often very dispersed over a very large network of local roads.

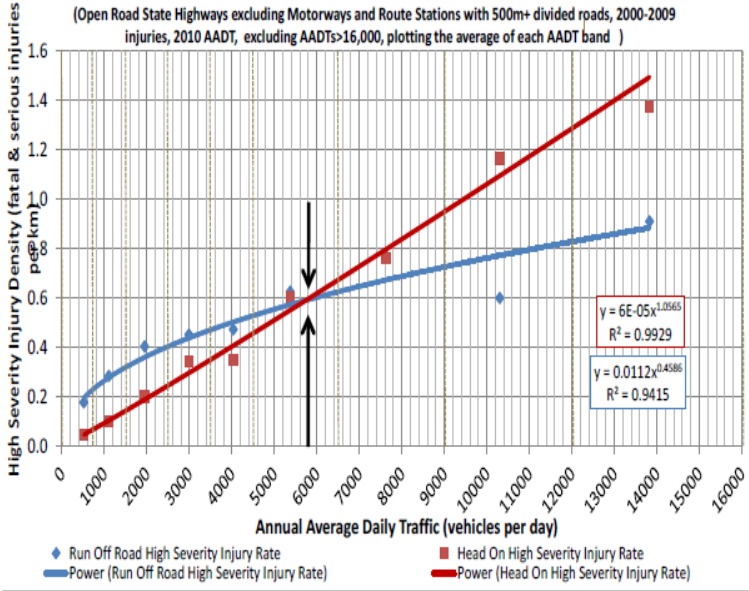
Again focusing on the Fatal and Serious state highway crashes we find that three crash types – run-off-road, head-on and intersection turning conflicts account for the vast majority of crashes ($\approx 85\%$). KiwiRAP, the High Risk Rural Roads and High Risk Intersections guides focus on these crash types.

Whilst the run-off-road crashes account for approximately over half of all rural state highway Fatal and Serious crashes, when we look at the casualty outcomes we find that head-on casualties are a sizeable problem accounting for approx 27% of all state highway DSI’s, and significantly higher in some of the heavier trafficked networks such as the Waikato Region.

Figure 2: Run-off-road and head-on high severity injury density

Source: High Risk Rural Roads Guide

In investigating the head-on casualty problem further we also find that on roads carrying over approx 6,000 vehicles per day (vpd), the density and rate of DSI’s exceeds run-off-road casualties. (Refer Figure 2). Similar results were found in Sweden (approx 4,000 vpd Source: Torsten Berg) and more recently in Victoria (7,000 vpd Source: Chris Jurewicz: AARB). Hence our recent increased focus on centreline and median treatments on higher volume roads with rumble strip centrelines, wide centreline



3. International Best Practice Advice

In March 2011, Torsten Bergh (Road Design & Traffic Engineering Strategist for the Swedish Transport Administration), and Dr Bruce Corben, (researcher at the Australian Monash

University Accident Research Centre), spent two weeks in NZ reviewing a range of major road improvement projects including the Roads of National Significance (RoNS) from a Safe System perspective. Their key findings and advice included:

- The rural traffic safety problems in NZ seem very similar to Sweden; single run-off lane departures, head-on and intersection crashes dominating.
- Whilst behaviour change programmes have served NZ well in the past they have not been successful in addressing human errors such as gap selection, lane keeping, inattention, fatigue etc. A guiding philosophy that explicitly acknowledges the limited intrinsic capacities of humans is essential to future success.
- Traditional road engineering features such as skid resistance, seal widening etc have led to an incremental reduction in trauma however a new strengthened approach is needed over the next decade if we are to achieve the desired results.
- On existing routes it is often feasible to retrofit high standards of safety and this should be pursued vigorously with a strategic focus. The Safe System Speeds cornerstone must be considered where Safe System improvements in infrastructure are either uneconomic or otherwise not possible.
- There appears to be good potential for major safety improvements and reduced costs in NZ with extensive use of side barriers.
- NZ has many 10m roads, sometimes with passing lanes, which could be retrofitted with side and median barriers to 1+1 or 2+1 (with additional passing lanes) as has been done in Sweden.
- Sweden introduced the American style 10-13m clearzones in 1980s. Experience has now shown barriers to be superior and clearzones are now only used in exceptional circumstances
- Safety experience in Sweden of large at-grade, high speed, intersections with auxiliary turning lanes has been negative. Conversely, roundabouts (10m radius central island) have been mainly very successful.
- Variable speed limit (to 60km/h) intersections have been trialled for a number of years and many more are being introduced.

4. Barriers versus Clear Zones

Consistent with the Swedish experience and advice, a number of research projects are being undertaken in Australia, in particular the Austroads ST1427; Improving Roadside Safety (AARB: 2010, 2011 & 2012) and work undertaken by Doecke & Woolley (2011) at the Centre of Automotive Research (CSAR) Adelaide have been challenging the effectiveness of clear zones from both a cost effective and Safe System perspective.

Austroads analysis of casualty crashes showed that 30% of all run-off-road casualty crashes occurred in wide clear zones exceeding 13m in width (a similar result was observed for fatal and serious injuries). It was also shown that there was an increase in the severity of run-off-road crashes occurring in wide clear zones. Whilst the proportion of run-off-road crashes to the left where an object was hit decreased with increasing clear zone width these object hit crashes were to some degree replaced by roll over crashes. The in-depth crash analysis of run-off-road crash records suggested that 74% of run-off-road crashes occurred with high

road departure angles (more than 15%) even if the initial lane departure angle was often lower. Driver recovery may occur in the first 4m if such a clear zone was available and that the angle of departure was relatively low. The research reinforced the view that the greatest safety gains would come from safely retaining errant vehicles on the road or in its close proximity.

A review of barrier crashes indicated that the combined chance of fatal and serious injury was lowest for flexible barriers. A review of median barrier performance showed that their provision is the most significant factor affecting the run-off-road and head-on crashes across medians. Flexible barriers were being cost-effectively retrofitted to medians previously considered of insufficient width to warrant a barrier. Significant crash savings were observed when such barriers were erected on narrow medians, or on roads which were previously undivided.

Doecke and Woolley (2011) found that the way in which clear zones have been implemented in many regions over the last forty years has been based largely on research performed in North America in the 1960's that recommended a nine metre clear zone. Current guidelines have acknowledged the limitations of the previous approach and now state that clear zone width should not be considered as an absolute value and is most effective for low angle departures. However, it is unlikely that full width clear zones will ever be implemented on many parts of the road network and there are still large gaps in knowledge as to the optimal mix between the provision of clear zones and barriers.

Doecke & Woolley examined a sample of 132 crashes to determine typical dynamics in single vehicle run-off-road crashes. The mean departure of vehicles that drifted off the road without losing control was 7.3° while for vehicles that were out of control it was 17.6°. Only 3 of the 18 vehicles where no fixed object was struck did not travel beyond a traditional 9m clear zone and that from simulations performed they found that the impact speeds at 9m exceeded the limits of a Safe System.

Our understanding of the optimum design and treatment of roadsides in the Safe System context is still evolving as research and experience is continuing. The studies referred to above all have their limitations particularly in respect to sample size, comparing barrier performances from different environments and the relatively limited use to date of wire rope barriers and, in general these studies are based on reported crashes that have occurred but have not quantified the extent of non reported crashes or run-off-road and recover incidents i.e. clear zones may be working well for a large number of incidents that go unrecorded. However based upon the research results to date, and advice by international experts, we can probably draw the following conclusions:

- A narrow clear zone (say 4m) will reduce a substantial number of hit object crashes and allow for the recovery of some drift off road crashes.
- There is evidence that the 9m clear zone may not be delivering the outcomes originally envisaged nor Safe System outcomes for run-off-road and out of control crashes.
- Flexible barriers appear to deliver the lowest severity outcomes from run-off-road and median crashes.
- Wide clear zones should only be provided where a substantial traversable width is easily achieved at a low cost.

Based upon the conclusions, the median and roadside aspects of the RoNS guidelines have been modified. They allow for a range of median widths from 4m (paved) to 7m (grassed) and a range of roadside treatments from a minimum barrier offset of 3.0m (desirably 4.0m) or very wide clear zones where practical and cost effective. The barrier of choice, to provide the lowest severity outcomes, is the flexible wire rope barrier system. The exceptions are likely to

be when high level (Test Level 5) containment is required or on high volume corridors where the cost and traffic delay effects of median barrier repairs could justify a more rigid median barrier option.

5. Motorcycle versus barrier issues

As motorcyclists have little or no capacity to absorb impact energy, most roadside objects, including barriers and signposts are a potential hazard in the incidence of a crash. Considerable international research is being undertaken in respect to motorcycle versus roadside barriers including a 3 – 4 year research project, jointly funded by the NZTA, at the NSW Injury Risk Management Research Centre (IRMRC). The findings to date have been published in Motorcycle Crashes into Roadside Barriers, Stage 1 (IRMRC 2010), 2 (IRMRC 2011) & 3 reports. Shorter papers have been published and presented by the same authors at various conferences (by Professor Raphael Grzebieta and Dr Mike Bambach et. al)

The research (2010a) found that of 1462 Australian and NZ motorcycle fatalities between 2001-2006, only 77 (5.4%) were positively identified as involving a roadside barrier. Four of these occurred in NZ from a total of 201 NZ motorcycle fatalities. The fatalities involving impact with a roadside barrier predominately involved semi-rigid steel with steel or timber posts (72.7%), followed by concrete (10.4%) and wire rope barriers (7.8%). This is largely driven exposure rates of each system. In 47% of cases, motorcyclists impacted barrier in the upright posture (predominantly touring motorcycle riders) and 44% slid into the barrier (predominantly sports motorcycle riders). Severe head/neck, thorax (highest incidence of maximum injury) and extremity injuries including amputations were found amongst motorcyclists that impacted all types of barriers. There is no evidence that any particular barrier type is any more or less injurious for motorcyclists than another and the 'cheese cutter' effect of wire rope barriers is a myth that needs to be strongly rebutted. (Source: Grzebieta presentation, Perth 2011)

Solutions exist to reduce motorcyclist fatalities but credible science must be used so as not adversely affect all road users and gains to date – rub rails and skirtings should not cause a vehicle to launch. At present no internationally recognised test standard exists for motorcycle barrier systems however Austroads (2011) suggests that given the low incidence of motorcyclists crashes involving barriers, it is unlikely that retrofitting would result in significant reduction in motorcycle fatalities.

6. Speed Management

As the Safe System approach is based around managing impact forces in crashes, the importance of speed effects in crashes cannot be over emphasised. The well accepted Nilsson's power model connecting changes in traffic speed and road trauma indicates that a 10% change in mean speed will result in an almost 30% change in the number of fatal and serious crashes.

However, altering speed limits alone, without engineering and/or severe enforcement will not result in similar changes in operating speeds.

Table 1 below gives an indication of appropriate speed limits for different road types and road user environments based upon the probability of survival "S" curves shown in Figure 1 (Page

1). Some of the best performing European countries, such as Sweden and Norway have “harm minimisation” speed limit philosophies based largely around these speeds Austroads members, including NZ, are all presently attempting to understand what the setting of speed limits will look like in the Safe System environment. However obviously there needs to be a balance between mobility and safety.

Table 1: Safe Speed Thresholds for different road types

Source: High Risk Rural Roads Guide (NZTA 2010)

Road types combined with allowed road users	Safe speed (km/h)
Roads with possible conflicts between cars and unprotected road users	30
Intersections with possible transverse conflicts between cars	50
Roads with possible frontal conflicts between cars	70
Roads with no possible frontal or transverse conflicts between road users	≥100

The Highway and Network Operations division of NZTA have commissioned Max Cameron of Monash University to replicate work he has undertaken in Australia on optimal speeds for the NZ state highway network based around the recently released classification system. This work, also being presented at this conference, suggests that the optimal speeds balancing social costs of crashes against time, vehicle operating costs and greenhouse emissions range from 105km/h for light vehicles on the motorway/expressway system down to 80km/h for light vehicles and 70km/h for trucks on the lower standard regional distributors and connectors. This research will help better inform any future discussions around the implication of any safe system speed limit reviews.

A number of ad hoc type speed management projects have already been implemented or trials proposed. Lower speed limits have been set along a number of high risk corridors such as SH2 North of Tauranga, SH2 Karangahake Gorge, SH1Dome Valley, SH2 Napier to Clive, SH2 Maramarua and SH1 Otaihanga plus others in the South Island. Variable speed limits exist in the Ngauranga Gorge area and variable speed trials are underway at some rural schools funded by the Road Safety Trust. Rural Intersection Activated speed warning signs are being proposed for high risk rural intersections. A further weather condition variable speed limit is also being investigated for the Kaimai Range portion of SH29 in the Bay of Plenty Region.

7. High Risk Rural Roads

Focussing our efforts on high risk rural roads taking a Safe System approach is a key Roads and Roadsides priority in Safer Journeys. In the state highway sector we are already well advanced in this with the initial release of the KiwiRAP Risk maps in 2008, which ranked our highways in terms of collective risk (fatal and serious crash density/km) and personal risk (fatal and serious crashes/veh km travelled). This was followed by the release of the KiwiRAP Star Ratings of the state highway network in 2010. In 2011 NZTA published the High Risk Rural Roads Guide, NZTA (2011) to assist all the Road Controlling Authorities in identifying high risk corridors, countermeasures and developing countermeasure programmes. The NZTA’s funding criteria has also been changed to recognise high risk rural roads as a high strategic fit.

In recent years we have focussed many of our safety programmes and initiatives such as rumble strips and barriers on the higher volume, high risk corridors. Our monitoring has shown that these efforts have been very effective with crash reductions on the KiwiRAP high and medium-high risk maps to have been far greater than the lower risk routes. The results of this KiwiRAP monitoring will be released to the public late in 2012. Monitoring has also shown a far greater reduction of fatal and serious crashes on corridors where they were installed versus a 8% reduction on corridors they were not installed. These relatively lower cost incremental improvements implemented through the minor works, safety retrofit and crash reduction programmes have produced good results, and will continue to do so. Future funding in these programmes will be combined and nationally prioritised and allocated to ensure we are getting the best returns from limited resources.

However to make significant safety improvements on some of the higher risk, higher volume corridors will require higher cost initiatives such as median barriers and side barriers and significant intersection form changes to make these highways forgiving of human error. This is confirmed by KiwiRAP Star Ratings project and the KiwiRAP analysis tool (KAT) that shows that changes such as delineation improvements; shoulder widening etc only marginally improve the road protection score (RPS) and Star Rating. Significant alignment changes, median barriers and roadside improvements are required to make a substantive change to the Star Rating. Whilst the RoNS, and the next wave of RoNS projects, will address some of these corridors, many of these will not occur for many years and there are also many other corridors that will not be addressed by the RoNS programme.

In 2010/11, NZTA commissioned Monash University (MUARC, 2011) to undertake some modelling of the effects of capital expenditure in different types of road safety engineering programmes. The outcome of this exercise, titled Macro Estimates of Target Setting (METS), demonstrated that we could get far better returns from redirecting a proportion of our present traditional capital and block programmes (Business as Usual) into Safe System projects such as rural routes and rural urban intersection transformations. This work is also being presented at this conference but indicated that a redirection of approximately \$104m pa (approx 10% of existing capital programme) into Safe System transformation programmes could result a further 1000 fatal and serious casualties saved (+16%) over business as usual over a 10 year period. The METS study along with a previous study of transposing the KiwiRAP data in our International Road Assessment Programme (iRAP) investment tool, both recommended a programme of approximately 400km of median barriers of 2+1, and over 2000km of side barriers. Projects such as the SH1 Rangiriri 2+1 project and SH1 Centennial highway have already shown what can be achieved by retrofitting barriers.

However Safe System transformation of many other existing corridors will require us to challenge many of our existing standards and guidelines to install barriers on very narrow medians on substandard alignments, across intersections limiting them to left turn in and out, narrower lanes and shoulders and side barriers installed on slopes etc. utilising the KiwiRAP risk map and star rating results, the SafetyNET software tool has been assessed against the treatment philosophy approach developed in the HRRRG. This indicates the requirement for approx 700km of Safe System transformation projects, 1900km of corridor improvements (side barriers etc), and 4800km lower cost improvements including speed management.

8. High Risk Intersections

Safer Journeys has focused improvement programmes on high risk urban intersections taking a safe system approach, as a high priority area. The NZTA has recently released the High Risk Intersection Guide (NZTA: 2012) for consultation. This covers both rural and urban intersections and includes the metrics on what defines high-risk, from both collective (crash density) and personal (crash rate) perspectives.

Intersections account for approximately 17% of all rural deaths and seriously injured (DSI's) and 48% of all urban DSI's. Pedestrians and cyclists make up 35% of DSI's at urban intersections. On the state highway network there are just over 200 fatal and serious intersection crashes each year of which 55% are rural and 45% on urban state highways, the vast majority of these are at crossroads and Tee intersections. As with head on crashes, intersection crashes often involve more than one vehicle and hence a greater number of casualties per crash than run-off-road crashes.

In accordance with the Safe System approach, to minimise the risk of fatal and serious casualties, side impact collisions speeds need to be managed to below 50km/h and vulnerable road user impact speeds to below 30km/h. Roundabouts are one form of intersection reasonably well suited to the Safe System approach as good roundabout design involve managing entry and circulating speeds to these levels, however cyclists in particular can be vulnerable in larger, higher speed multi-lane roundabouts.

Whilst traffic signals separate many conflicts by time allocation, in the inevitable event of human error or misuse, impact speeds and casualties can be severe, particularly in higher speed environments. As such traffic signal designs in higher speed environments are not necessarily consistent with the Safe System approach. To assist in managing impact speeds at signalised and priority control intersections, some European countries have the intersections raised on elevated platforms (primarily in urban pedestrian environments) or have raised platforms on the approaches. However these are typically only used in speed environments up to 60km/h.

Obviously on the state highway rural network the vast majority of at-grade intersections are not Safe System compliant but there is no expectation that these will all be addressed. Our focus will be on those that pose the highest risk, with high conflicting flows, in high-speed environments and with a high severity crash record or high severity crash potential.

Rural roundabouts are likely to become more prevalent on sites where maintaining the corridor efficiency is not of primary importance and/or grade separation is not cost effective or affordable. In addition we will be trialling lower cost speed management techniques such as Rural Intersection Activated Warning signs (RIAW's) at a number of rural sites over the next couple of years.

9. Procedures, Processes, Manuals and Training

Embedding the Safe System approach will take some considerable effort and time as our existing 'driver blame' culture, and our design and operation practices have been with us for many years. It requires us to recognise ourselves as system designers and take responsibility for the safety outcomes of what we do both at work and outside work. Many of our existing practices will need to change. Austroads are already starting the review of the Road Design series from a Safe System perspective although this will take many years.

The NZTA is currently looking to review the Safety Audit procedures as one mechanism to expand the knowledge and understanding of the Safe System and ensuring that at least our new projects are more forgiving of human error. The auditors will need to identify areas where errors may occur, and where crash forces may exceed the limits of a Safe System.

Raising the awareness of the Safe System, in the wider industry such as our key partners, consultants, suppliers and organisations such as utility authorities is underway. The NZTA has developed a 2 day Safe System (101) training course for internal and external personnel

to give an overview of the Safe System principals and countermeasures across all four of the Safe System cornerstones; Safe Roads and Roadsides, Safe Speeds, Safe Road Use and Safe Vehicles. Four workshops are being run around the major centres in late 2012 with more proposed next year.

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