Outcome Based Management of Roadside Hazards

Moon, W.[1] Mihailidis P.[2]

[1] VicRoads

[2] Trafficworks Pty Ltd

Abstract

Run-off-Road crashes represent 55% of all fatal crashes and 32% of all serious casualty crashes in Victoria. These crashes account for 50% of all serious casualty crashes in rural areas. In 2010, 66% of all run-off-road fatal crashes involved collisions with fixed roadside objects and 70% resulted in serious casualty crashes.

Crash statistics show that errant vehicles continue to leave the carriageway and strike hazards beyond the clear zone. This paper discusses the development of engineering treatments along sections of rural highway in Victoria, using an outcome-based approach with the intent to shield all roadside hazards along the treatment lengths and challenges the current clear zone approach.

The site assessments were based on the proven Safe System approach to treating roads and roadside hazards, recognising that human error is unavoidable and that there is a natural limit to the amount of force that the human body can endure.

It is anticipated that the initiatives proposed in this paper regarding the design and installation philosophy of safety barrier, as one of a host of treatments to reduce the road toll, will make a significant contribution towards our road safety objectives, ideally across all projects.

This paper explores the new initiative for an outcome-based approach to treat roadside hazards that is supported by recent research in the area.

Keywords: first principles, outcome based approach, clear zones, safe system, road safety barrier, risk, exposure, system failure

Introduction

This paper proposes that a Safe System approach, driven by first principles based policy and supporting guidelines (that no one should be seriously injured or killed in roadside crashes), should maximize the use of a contemporary and now technically advanced road safety countermeasure – the road safety barrier – as the first treatment of choice.

This outcome-based approach, based on first principles, aims to prevent any vehicle from leaving the road and entering the roadside - particularly in rural higher speed environments. This, in itself, will significantly underpin the outcome-based approach of the Safe System's 'vision zero' in which a compliant driver who enters the system is not seriously injured or killed.

This paper will also demonstrate, with a review of recent research, that the current standards-based approach of using clear zone principles is being questioned and requires review.

Furthermore, this paper will explore safety barriers as the preferred first-principle treatment to achieve safe system outcomes.

The paper will then provide examples of brown field and green field approaches that reflect an outcomes-based approach and aim, ideally, to prevent any vehicle from leaving the road and entering the roadside - particularly in rural higher speed environments.

Ultimately, this paper aims to raise awareness, discussion and a change to policy, standards and guidelines to subsequently enable road safety practitioners to investigate, develop and implement alternate treatments as the first principles, such as safety barriers and other counter measures, to address rural run-off-road crashes instead of clear zone principles. This would align more closely with Safe System aspirations.

This paper is a road safety practitioner's perspective and is largely centred on our opinion regarding the preferred direction of policy change. In doing so, we believe it is supported by a critique of recent research in the area of clear zones and the Safe System – rather than an exhaustive review of all the evidence.

Method

Clear zone principles are outlined in the Austroads Guide to Road Design, Part 6. These are the current guidelines and long-standing first-principles that road safety practitioners use for managing roadside hazards.

This paper will examine three research studies on clear-zones that challenge current principles and suggest implementing Safe System principles. This will highlight the appropriateness of using these studies in developing treatments for rural run-off-road type crashes according to Safe System principles.

In terms of contemporary clear-zone research, this paper will examine the findings of the following three papers:

a) Outcome-Based Clear Zone Guidelines (Monash University Accident Research Centre, 2008) – unpublished document
b) Effective use of clear zones and barriers in a Safe System's context (Centre of Automotive Safety Research, Doecke and Woolley, 2010)
c) Austroads Report – Improving Roadside Safety: Summary Report (Australian Road Research Board 2013).

This paper acknowledges that clear zone principles inform current practice. As such, reference will be made to Austroads Guide to Road Design, Part 6: Roadside Design, Safety and Barriers and to the VicRoads Supplement to the Austroads Guide to Road Design in order to contextualise the abovementioned studies.

Results

Current road safety principles used to provide safer roadsides typically involve a clear-zone based approach to road design and counter-measure treatments. The VicRoads Supplement to the Austroads Guide Part 6 states that a recovery area is the area required for errant vehicles leaving the carriageway to regain control or stop safely. In order to achieve a reasonable degree of safety, the guide recommends that road designers use an area smaller than the recovery area called a ‘clear zone’.

This ‘clear zone’, according to the Guide, is a compromise between the recovery area required by an errant vehicle, the cost of providing this area, and the probability of an errant vehicle encountering a hazard in this area. The Guide does recommend that a ‘clear zone’ should be kept free of non-frangible hazards where economically and environmentally possible. If a major hazard, that is one that would be expected to cause serious injury or death, be present just outside the clear zone then consideration must be given to shielding this hazard even though it is outside the defined clear zone.

In the Austroads Guide to Road Design, clear zone widths range between 3.0m to 14.0m. These clear zone widths are measured from the edge of the traffic lane, though the method for determining clear-zones does differ in Victoria and in New South Wales. The Guide does note, however, that where a specific investigation indicates a high probability of continuing crashes then the clear zone widths may be greater than those listed in the table.

The VicRoads supplement states that about 80 to 85 per cent of vehicles travelling at 100km/h can regain control or recover in a width of about 9m when measured from the edge of the traffic lane. The supplement also states, however, that to enable the recovery of 100 per cent of vehicles is substantially wider and generally impractical to achieve. According to the Austroads guide, this is impractical as a greater clear zone requires a wider area beside the road that in turn substantially increases the cost of providing a road, even for a modest percentile increase. As such, according to the Guide, the incremental risk reduction afforded by increasing the width of the area does not generally warrant the expense. This is based on the assumption that, in general, hazards outside the recovery zone are the same as those within the recovery zone. However, the Guide does state that where the potential consequences of a hazard outside of the recovery zone are deemed to be particularly severe then the risk should be taken into consideration and managed.

Nevertheless, the first principle in current road safety practice, when following the Austroads guide, is to manage roadside hazards primarily by hazard removal in the context of clear zone widths.

In contrast, the abovementioned papers conclude that current clear zones need to be significantly wider to meet Safe System principles and that regaining control once off the road is unlikely.

As such, a review of the latest research into clear zones will be provided below in three parts relating to the individual research undertaken by Monash University of Accident research (MUARC), Centre of Automotive Safety Research (CASR) and Australian Road Research Board (ARRB).

1) MUARC

The research into clear zone guidelines titled ‘Outcome-Based Clear-Zone Guidelines’ (MUARC, 2008) states that Victoria’s largest category of road trauma continues to involve errant vehicles leaving the roadway, resulting in death or serious injury to the vehicle occupants, with over 50% of deaths on rural roadways occurring as a result of vehicles running off the road.

MUARC's research involved a theoretical assessment of vehicles leaving the roadway on varying departure angles, for varying speeds to determine the lateral displacement and the associated speeds. This was undertaken as a means of establishing an 'outcome-based approach to determining appropriate clear-zone guidelines on a case-by-case basis in Victoria'.

The research showed that in 9m clear-zones, with a driver reaction time of 2.5 seconds (based on a motorist driving longer distances on rural roads where drowsiness and fatigue are factors and/or more appropriately, for guidelines to consider the 'best case' scenario) leaving the roadway at a speed of 100km/h, regardless of the departure angle, all crashes would result in death to the occupants of an errant vehicle.

It also shows that in order to achieve Safe System acceptance levels, clear zones would need to be 42m for a departure angle of 15 degrees, on roads with speed limits of 100km/h such as on rural roads in Victoria.

MUARC evaluated a range of departure angles, which included 5, 10, 15, 25 and 45 degrees using reaction times of 1.2 and 2.5 seconds for various speed limits. In summary, this data can best be reflected in Table 1 for the 15 degree angle of departure scenario;

Table 1 - Summary of clear zone distances for Safe System compliance

Speed (km/h)	110		**100**		80		60		50	
PRT (sec)	1.2	2.5	1.2	**2.5**	1.2	2.5	1.2	2.5	1.2	2.5
clear zone distances for Safe System compliance (m)										
100% chance of death*	27	37	19	**30**	6.8	15	5	11	4	9
50km/h impact speed#	37	48	30	**40**	18	25	7	14	4	9
Safe System^	40	50	33	**42**	20	27	10	16	7	11

- *impact at the speeds predicted at these clear zones have a probability of death of 100%
- #frontal collisions at 50km/h above which the risk of fatality increases rapidly
- ^deemed operationally low risk

The shaded column in Table 1 is typical of run-off-road crash scenarios and the clear zone required is five times larger than current clear zone requirements.

The MUARC report is clear that the methods used were all theoretically derived using the laws of physics. Emphasis was placed on the equation defining the kinematics of a vehicle travelling across a smooth grass surface (an acknowledged conservative assumption) once it left the road at given speed using different angles of departure and using two different reaction times. Using this method, the authors determined the speed profile of an errant vehicle as a function of the lateral displacement from the road and in doing so have used similar scientific means to determine the probability of serious injury or death when striking a narrow, rigid object positioned beyond the clear zone.

As such, they have provided clear zone widths that align with the Safe System approach (as noted in the summary provided in Table 1).

The calculations are based on frontal collisions and it is noted that side impact collisions are typically considered higher risk, and as such, may further extend the proposed clear zone widths.

This theoretical approach is comparable to real-life scenarios that have been examined and reported separately by CASR.

2) CASR

CASR undertook simulator assessments into 'Effective use of clear zones and barriers in a Safe System's context', presenting the findings of the study at the 2010 Australasian Road Safety Research, Policing and Education Conference.

The study reviews the use of clear zones as the preferred rural roadside treatment to address crashes into fixed roadside hazards. Crash samples were obtained from CASR's comprehensive crash records to investigate the dynamics of a single vehicle run-off-road crash, with a focus on the departure angle, lateral displacement and the associated speeds.

Three types of run-off-road crashes were simulated. A crash which involved a car drifting off the road (this is similar to the low departure angle MUARC evaluated), a single yaw crash in which a vehicle lost control in one direction and left the road at a departure angle of 19 degrees (this is similar to the 15 degree MUARC scenario in Table 1) and a double yaw crash which represents loss of control in one direction and then overcorrection in another (this scenario was not part of the MUARC study).

All the simulated crashes were for a 110km/h speed zone.

The CASR analysis shows that for a vehicle that leaves the road travelling at a speed of 110km/h, at a departure angle of 19 degrees, the lateral displacement of 47m was required to reduce vehicle speed down to 30km/h. A summary of the clear zone results are shown in Table 2.

As such, it was reported that the traditional clear zone of up to 9m was deficient in providing adequate space for errant vehicles to safely reduce speed to 30km/h – a speed considered unlikely to result in serious injuries to the occupants of an errant vehicle.

The simulator results determined that safety barrier should either be placed as close to the road as practicable or provide a clear zone of approximately 47m away from the road edge. It was further shown through the CASR analysis that barriers placed at an offset of 3m from the edge of the road, with impact in the mid-span of the barrier system, should not result in death or serious injury to the occupants of an errant vehicle, achieving a Safe System outcome. This is suggesting that the barrier in this location is not a hazard, but acknowledges, due to the relatively small sample size, that further work is required to increase the robustness of the findings.

Table 1 – Summary of CASR clear zone scenarios

Case	Type	Driver scenario	Initial Speed	Departure Angle (degrees)	Total lateral displacement (metres)	Lateral Displacement at 30 km/h (metres)	9 metre impact speed (km/h)
A	Single Yaw	Recovery	110	19	48	47	76
A	Single Yaw	Braking	110	19	24	21	73
B	Double yaw	Recovery	106	9	29	29	86
B	Double yaw	Braking	106	9	20	18	73
C	Drift Off	Recovery	100	10	6	N/A	N/A
C	Drift Off	Braking	100	10	13	12	54

The shaded column in Table 2 is typical of run-off-road crashes and the clear zone required is around five times larger than current clear zone requirements.

The following study limitations should be noted:

- Limited sample of crashes was used; and,
- Coefficients of friction used in the simulations were not measured values but were assumed typical values.

In relation to the simulator studies undertaken by CASR, they acknowledge that work on this subject is ongoing and that in due course the sample of crashes will increase to around 130 in the final results, which will increase the confidence of the findings. This is important given the random nature and the numerous variables in run-off-road crashes.

3) ARRB

ARRB has been working for Austroads reviewing roadside safety and the report 'Improving Roadside Safety' is at stage four in the process and provides a summary report. The work has been primarily undertaken from 2008 to 2012 and it seeks to provide guidance on hazard management, treatment selection and barrier placement.

The report has investigated different clear zone widths and their effectiveness, frangible roadside structures and safety barrier selection and placement.

In relation to clear zones, the earlier stage two interim report states that motorists who have left the road surface and entered the roadside at high speeds (eg 100km/h) do not have sufficient time for deceleration, corrective action and recovery. (Austroads, 2011)

The ARRB study concludes that the average braking distance under skidding required to reach an impact speed of 40km/h was shown to be 119m for a roadside surface of loose gravel and 201m for wet grass with a reaction time of 2.0 seconds and an initial departure speed of 100 km/h.

The report subsequently advises that an enormous clear zone of 53m (lateral departure) would be required for vehicles leaving the road to achieve deceleration to a survivable speed (at a departure angle of 15 degrees at 100km/h with a roadside surface of wet grass). The report also compares this to the similar findings reported in the CASR study (2010, 2011).

In terms of departure angles, the ARRB report shows that the majority (74%) of run-off-road casualty crashes in Victoria occurred at departure angles exceeding 15 degrees and they refer to both the CASR report and Mak, Sicking and Coon (2010) which all similarly conclude that the mean average departure angle is in the order of 17 to 18 degrees. This means that the crashes typically occur 'into' the roadside rather than 'along it'.

In contrast, the minority of run-off-road crashes appear to be drift-off events where the motorist leaves the road at shallow angles and as such, has a higher chance of full recovery within the first 4-5m if their vehicle remained under control and if a recovery was attempted. This scenario appears to be associated with straighter aligned road geometry.

It is acknowledged that the ARRB study covers broader aspects for improving roadside safety but its focus on run-off-road crashes and clear zones is particularly noteworthy, and in summary, is consistent with the work of MUARC and CASR.

Discussion

Contemporary Clear Zone Research

In terms of summarising the abovementioned studies, the parameters of speed (100 to 110 km/h), departure angle (approx 15 degrees) and reaction time (2.0 sec) are typical of run-off-road crashes on rural roads.

It is arguable that the 50km/h impact speed used by MUARC should be lower and perhaps the 30km/h speed allowed by CASR is more appropriate (for side impacts). At 50km/h, the occupants of an errant vehicle may sustain serious injury whereas at 30km/h, the occupants are unlikely to sustain serious injury. This recognises that while human error is unavoidable, there is a natural limit to the amount of force that the human body can endure. Nonetheless, regardless of either impact speed, both studies show that to significantly mitigate the risk of injury and have compliance with Safe System principles, clear zones that are around five times greater than the existing clear zones are required.

Specifically, the theoretical study by MUARC found that for a vehicle leaving the road travelling at 100km/h, at a departure angle of 15 degrees, approximately 42m of clear zone is required to reduce the likelihood of death to below 10 per cent. Similarly, CASR simulations show that travelling at 110km/h, at a departure angle of 19 degrees, approximately 47m of clear zone is required to be Safe System compliant. Likewise, ARRB reported that a clear zone of 54m would be required for a vehicle leaving the road at 100 km/h at a departure angle of 15 degrees.

The findings by MUARC, CASR and ARRB are all notably similar. They show that the current clear zone standards are not Safe System compliant and that the chance of survival at the associated impact speeds is minimal to zero.

As a means to work towards the Safe System aspirations, a process of evaluating risk and exposure should be adopted to prioritise safety barrier treatments which, if not achieved in the short to medium term, would lead the way towards the ideal aim of barriers fully protecting the roadside.

The clear zone principles will never achieve this safety outcome as roadsides are typically not wide enough to accommodate a drivable hazard free zone of approximately 45m.

Aside from the limited roadside width that inhibits safe system clear zones, the high social and environmental value of road reserves is a significant issue that is difficult to resolve due to the environmental constraints under state and federal legislation that protects remnant native vegetation.

The ARRB report notes that in the short to medium term, safety barriers may provide a cost effective treatment for high-risk locations and that, in the long term, active vehicle safety features as well as Safe System road and roadside design are options for severe risks on higher traffic volume roads. On lesser traffic volume roads, it may be difficult to justify the high level of infrastructure required to meet Safe System requirements.

Nevertheless, clearer direction regarding the widths required to meet Safe System clear zone requirements would lead to improved road design and counter measure treatments by road safety practitioners. For example, it is evident that compliance with current clear zones results in hazards that are either constructed marginally outside the clear zone and/or existing hazards that remain marginally outside the clear zone.

In terms of the high cost of infrastructure to treat roadsides with safety barrier, which is the ideal outcome, the cost benefits should be further scrutinized and industry should be encouraged to consider lower cost barrier systems. As a minimum, it would be appropriate to acknowledge that safety barrier is the only effective treatment to meet Safe System requirements in terms of run-off-road crashes. Ideally, the aim should be to install it as the first treatment of choice when funding permits, and after which, if constraints limit further safety barrier, then careful consideration of lesser effective treatments be considered and duly acknowledged.

Further investigation is required and a cost-benefit analysis undertaken in order to compare the cost of installing safety barrier versus the clear zone provision of sufficient width to meet Safe System principles.

ACRS policy position on road safety barrier system

The ACRS have published a policy on the use of road safety barrier systems. The policy states that road safety barrier systems should only be installed at locations where the risk of injury resulting from a crash with the device installed is much less than the risk without the device.

In line with the Safe System approach, the policy also states that where these devices are installed, barrier systems should be designed so that the severity of a crash with the system is reduced to human tolerance levels.

The objective of the policy is to improve the intrinsic safety of the road environment and thus reduce the consequences of driver error.

The policy states that, "as community attitudes increase demand for safer roads, areas previously considered as (safe) clear zones may now in fact be classed as very unsafe roadside areas and hence, a road safety barrier is required. Installation of a barrier in such situations, while still presenting a certain level of roadside safety hazard, dramatically reduces the risk of injury to the majority of road users."

Principle Based Policy and Guidelines

In relation to a principles based approach, and on the reasonable conclusion that the current clear zones are inadequate based on the research by MUARC, CASR and ARRB, road authorities should evolve accordingly to reflect outcomes which align with the Safe System vision.

Figure 1 demonstrates an example of a principles based approach at policy level.

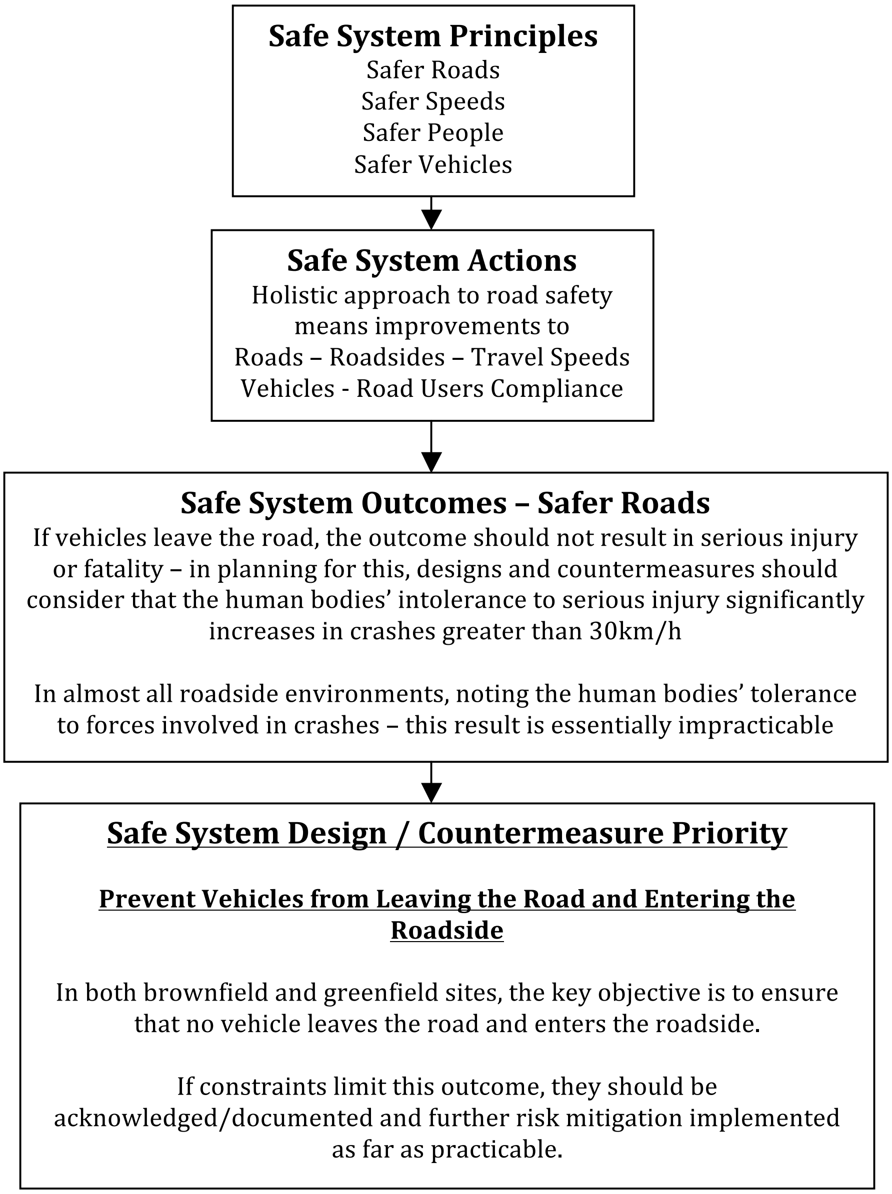

Figure 1 – Principles based policy approach for Safe System outcomes

Figure 1 sets out a process that starts with Safe System Principles, outlines actions required to achieve these principles, with due consideration to the human tolerance levels in a crash situation, and proposes countermeasures for Safe System design, with the ultimate aim of ensuring that no vehicle leaves the road and enters the roadside.

Safer Roads Infrastructure Program, Victoria

In Victoria, the Transport Accident Commission's (TAC) Safer Roads Infrastructure Program (SRIP4) comprises of a run-off-road program which evaluates, develops and delivers projects with a variety of countermeasures based on risk and exposure related to run-off-road crashes.

The SRIP4 program is fundamentally based on the principles of the Safe System.

In terms of the run-off-road component, the primary treatment is road safety barriers with the preferred system being flexible barriers such as wire rope. However, hazard removal (based on clear zone principles) currently ranks reasonably high as a treatment option for managing run-off-road issues (Austroads, 2010).

Other treatments can include tactile edge lines, improved signage, and delineation.

Shoulder sealing is another treatment option but the cost-effectiveness of this treatment is also questionable given the high cost to construct shoulders and the relatively limited ability to prevent vehicles from leaving the road and entering the roadside. As such, an errant vehicle that leaves the roadway travelling at 27m/s at a departure angle of between say 15 degrees, it is unlikely to correct on a 1.5m shoulder and regain control, particularly if fatigued. The safety barrier on the other hand will ensure that the vehicle does not strike a rigid roadside hazard.

The National Road Safety Strategy 2011-2020 'aims to set out a path for national action on reducing fatal and serious injury crashes on Australian Roads, coinciding with the International Decade of Action for Road Safety'. The Strategy is founded on the internationally recognised 'Safe System' approach formally endorsed by the Organisation for Economic Co-operation and Development (OECD).

Similarly, Victoria's Road Safety Strategy 2013-2022 sets out a vision of ZERO deaths and ZERO serious injuries on the states roads. While this is the ideal, the strategy outlines that the target to achieve this vision for the next 10 years is to:

- Further reduce the number of people who die on Victorian roads by more than 30 per cent.

- Further reduce the number of people who are seriously injured on Victorian roads by more than 30 per cent.

Road trauma in Victoria costs lives, with around 280 people a year (or 5 people a week) losing their lives on our roads. In dollar terms, road trauma currently costs Victoria over $3.0 billion dollars per annum

The Government is committed to increasing the safety of our roads and roadsides through engineering measures and safer road infrastructure. Improving our roadsides to reduce the likelihood of a run-off-road crash resulting in serious injury or death to the occupants of an errant vehicle can only occur by implementing a Safe System approach. This approach challenges the current clear zone principles and should consider the tried and tested engineering solution of safety barrier installation for shielding roadside hazards.

Brownfield Treatments – Safe System Outcome Based Approach

An example of a Safe System outcome-based approach is evident in a recently announced SRIP4 project for a 14km section of the South Gippsland Highway in Victoria. This project adopted an outcome-based approach of no fatal or serious run-off-road injuries within its treatment length with the objective that no vehicle should leave the road and enter the roadside.

Based on current clear zone guidelines, the existing clear zone for this road is 7.3m. However, a review of run-off crashes in this relatively high-standard road showed that approximately 50 percent of crashes in which vehicles left the road occurred outside the clear zone of 7.3m. All crashes outside the clear zone resulted in serious injury. In order to reduce an errant vehicle to a safe speed, based on the MUARC study, roadside clearing, terrain modification and maintenance would have been required for over 42m. This was clearly impracticable due to limited roadside width to achieve this as well as the social, economic and environmental limitations associated with clearing the roadside and converting it to a drivable standard. As such, clear zone standards were not part of the project development and a safe system approach was implemented.

Road safety barriers will be installed for approximately ninety percent of the treatment length. The ten percent without safety barriers related to sections that were either side road intersections or private access points. The project will provide 86 percent of flexible barrier (wire rope safety barrier) and 14 percent of w-beam guardrail barrier.

Hazard removal will only be implemented in locations where barrier cannot shield the roadside, for example, in the openings at intersections and access points as well as to facilitate barrier deflection.

This pilot project is a model for the Safe System and was driven by an outcome-based approach of no fatal or serious injuries with the objective that no vehicle should leave the road and enter the roadside in this higher speed rural environment.

Similarly, another project was developed in Victoria on the Bass Highway over a 10km treatment length. This road has a very high standard formation of divided carriageway with duplicated lanes and sealed shoulders, which was designed and constructed according to clear zone standards. The project will treat high and medium risk roadside areas by the addition of wire rope safety barrier which, including previously existing safety barrier, will now shield approximately 70 percent of the roadside. This run-off-road barrier project is due for construction in 2014 and is responding to 82 percent of crashes being run-off-road crashes comprising of two fatal crashes, seven serious injury crashes and one minor injury crash.

As governments and road authorities invest in solutions, it is critical that the Safe System approach is taken into consideration in order to achieve this long-term outcome.

Greenfield Treatments – Safe System Outcome Based Approach

One of the most substantive constraints in achieving Safe System outcomes in greenfield projects are the current design standards which, although slowly transforming to align with the Safe System, are failing to move quick enough to adequately embrace the Safe System.

Brodie, Bergh and Corben confirm that to meet the Safe System vision in the future, it is vital to adopt Safe System standards from the outset, when new road projects are being planned, designed, constructed and operated. This will necessitate challenging traditional standards at every step. This equally translates to brownfield sites, which in almost all cases use traditional design standards when considering countermeasure treatments.

In terms of designing greenfield projects, clear zone widths of approximately 42m would add considerable cost to the project and will have an environmental and social impact. As such, clear zone widths of around 42m are an unlikely option.

However, Brodie, Bergh and Corben propose that a Safe System cross-section for new road infrastructure is potentially lower cost and will provide improved Safe System outcomes. They conclude "that when the conventional standards are challenged, it will be possible to deliver new, major additions to the principal network that cost substantially less, make a major long-term improvement in safety outcomes and create a smaller 'environmental footprint' on highly valued landscapes. By challenging conventional standards for median widths, traffic lane widths and shoulder widths, as well as the standards for the use of flexible mid-barriers, and flexible side-barriers instead of clear zones, the total width of the road reserve can be reduced from around 36m to 21-22m, representing a 40% reduction. With this reduction come lower capital and maintenance costs for infrastructure in general, including most notably, the costs of grade-separated structures along the route, as well as superior safety performance (approximately an order of magnitude better than today's standards deliver)." **(**Brodie, Bergh and Corben, 2013).

The standards approach typically used by road safety designers and key decision makers in road design is a 1960s clear zone philosophy. This standard is now arguably outdated in light of contemporary research, which states that clear zones need to be significantly wider to meet the adopted Safe System philosophy. As such, this philosophy should be reviewed particularly when significantly better road safety outcomes are expected by state or territory road authority targets such as the Safe System Vision Zero approach.

Road Safety Barrier Improvements

The types of safety barrier systems have improved significantly since the 1960s. Advancements in the design, development and crash testing of safety barriers over the past fifty years, allows these systems to be installed with a high degree of confidence, with proven outcomes aligning with the principles of a Safe System.

This has been achieved through the introduction of flexible barrier systems such as wire rope safety barriers, as well as advancements in crash attenuator devices. Research and development in the area of these devices has seen a marked improvement in the types of terminals currently on offer. These terminals absorb the energy of an impacting vehicle and are designed to redirect an impacting vehicle away from a hazard and back towards the road, reducing the likelihood of death or serious injury to the occupants of an errant vehicle.

Wire Rope Safety Barrier is a more forgiving flexible barrier system. The system has been crash tested and is used in many developed nations around the world.

System Failure

In recent times, some higher standard roads have been treated for run-off-road crashes. These roads were designed according to clear zone principles, including hazard removal, but have since been investigated and treated with a Safe System approach. This highlights that even when roadside hazards are somewhat removed from the immediate traffic lanes, ie outside the clear zone, run-off-road casualty crashes continue to occur and the clear zone standards need to be reviewed. Examples of these scenarios are common and some include the duplicated sections of the Princes Highway (east) between Melbourne and Traralgon, the duplicated section of the Bass Highway between Lang Lang and Grantville and the duplicated section of Princes Highway (west) between Laverton and Little River, which have all had sections treated with additional road safety barriers.

In practical terms, it would be difficult to regain any meaningful control of a vehicle at a speed of 27m/s (100km/h) when on a non-drivable, unsealed surface (once off the road surface). The process of leaving the road often also leads to over correction and run-off-road crashes on the opposite roadside. Hence, within a second or two of leaving the road an object can be struck up to 30m from the roadside depending on the departure angle.

Wundersitz & Baldock (2011) report that a significant proportion of run-off-road crashes that result in fatal or serious injury are due to normal road user error and this is a 'system failure'. The Safe System approach, including the development of forgiving road, roadside infrastructure, and other initiatives including appropriate speed limits, have the potential to reduce road trauma and these types of system failures.

<u>Safe System</u>

With the relatively recent introduction of the Safe System into the road safety industry, it is now acknowledged that during every step of the road design and road safety process, current standards will need to be challenged and changed (Brodie, Bergh and Corben, 2013).

At the same time, the most significant rural crash problem in Australia is run-off-road crashes and as such, researchers and road safety practitioners have focused on how to improve this problem. This has led to the development of many research projects that investigate this issue and aim to mitigate the rate of run-off-road crashes. While an in-depth analysis of all these studies is beyond the scope of this paper, a comparative analysis needs to be undertaken in order to provide a solution to this problem.

Subsequently, this paper has focused primarily on a review of three studies in relation to clear zone performance to determine how effective the traditional road design standard is in achieving Safe System outcomes. The results show that traditional clear zone standards are deficient in providing adequate space for errant vehicles to safely reduce speed to 30km/h (a speed considered unlikely to result in serious injuries to the occupants of an errant vehicle).

The MUARC study showed that with the 9m clear-zone requirements, applying a driver reaction time of 2.5 seconds, leaving the roadway and entering the roadside at a speed of 100km/h, regardless of the departure angle, the probability of death (or serious injury) as a function of impact speed is 100 percent. The work undertaken by CASR and ARRB is notably similar in their conclusions.

The concept and value of clear zones should be reviewed when managing and treating run-off-road crashes, particularly in light of the Safe System objectives. In doing so, clearer direction regarding the widths required to meet Safe System clear zone requirements would lead to modified and improved thinking by designers and road safety practitioners

Furthermore, the aspect of design standards should also be questioned in regards to what the real objectives are, that is, whether it is economics or road safety outcomes. Ideally the aspect of ‘balance’ between these objectives should be removed and the standards set appropriately in line with Safe System aspirations to then allow the available resources to achieve as much as possible.

Specifically, consideration should be given to acknowledge that safety barrier is the only effective treatment to meet Safe System requirements in terms of run-off-road crashes. Clearly, constraints (most likely cost) will limit the ability to fully achieve this after which careful consideration of less effective treatments is then considered and duly acknowledged before implementation.

Conclusions

In conclusion, the current clear zone standards should be reviewed in terms of achieving Safe System objectives.

A significant directional change in standards is required to make meaningful improvements to the single biggest issue causing road trauma in rural Australia, run-off-road crashes.

This change should adopt a principles based approach to achieve Safe System outcomes, which needs to start at the highest policy levels. The answer is not clear zone / hazard management but rather a quantum shift to a principle based approach to simply aim to prevent any vehicle leaving the road and entering the roadside that would then be supported by renewed standards and guidelines.

The three studies above indicate that safety barriers are a preferred solution compared to clear zone guidelines to provide a Safe System solution. This implies that any hazard or object at any distance within a road reserve is not acceptable and hence, safety barrier design that eliminates a vehicle leaving the road is the ultimate ‘standard’.

Recommendations

It is recommended that:

1) the findings of this report be considered by Austroads, along with contemporary clear zone research, in order to review current clear zone principles with the view to adopt Safe System principles for the management of run-off-road crashes. This will ultimately promote improved safety outcomes on our roads and will shift current practice to an outcome-based policy with supporting guidelines.

2) road safety practitioners, researchers and others who are determined to improve the safety of the nation’s roads should be involved in these discussions. A collaborative approach amongst all concerned will provide the best outcome for safer roads.

References

Australasian College of Road Safety. *Road safety barrier system – ACRS Policy Position.*

Australian Road Research Board. (2013) *Austroads Report – Improving Roadside Safety: Summary Report.*

Australian Transport Council. (2011) *National Road Safety Strategy 2011-2020.*

Austroads (2010). *Guide to Road Design, Part 6: Roadside Design, Safety and Barriers.*

Brodie, Bergh and Corben. (2013) "*Regarding road safety*" Email to Moon W. 16 July 2013.

Candappa, N., Corben, B. & Logan, D. (2008) *Outcome-based Clear Zone Guidelines: Final Report.* Monash University Accident Research Centre. Commissioned by VicRoads (unpublished).

Doecke, S. & Woolley, J. (2010) Effective use of clear zones and barriers in a Safe System's Context. *Australasian Road Safety Research, Policing and Education Conference. Centre for Automotive Safety Research, The University of Adelaide.*

Jurewicz, C, Steinmetz, L, Phillips, C, Cairney, P, Veith, G & McLean, J 2013, *Improving roadside safety: summary report*, Austroads, AP-R437-13, Sydney, NSW.

State Government of Victoria. (2013) *Victoria's Road Safety Action Plan 2013-2022.*

State Government of Victoria. (2013) *Victoria's Road Safety Strategy 2013-2022.*

VicRoads (2011) *VicRoads Supplement to the Austroads Guide to Road Design, Part 6: Roadside Design, Safety and Barriers.*

Wundersitz, LN. & Baldock MRJ (2011) The relative contribution of system failures and extreme behaviour in South Australian crashes. *Centre for Automotive Safety Research, The University of Adelaide.*