CURTIN - MONASH ACCIDENT RESEARCH CENTRE

C-MARC

FACT SHEET NO. 7

SAFE ROADS AND ROADSIDES

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1. Purpose of this Fact Sheet

The purpose of this document is to outline the safety benefits that can result from road managers applying the principles of Western Australia's *Towards Zero* road safety strategy.

2. Roads and roadsides and traffic safety

The quality of road infrastructure design plays a fundamental role in crash risk and in the severity of injuries in the event of a crash. This role is critical in two instances: in the initial design of the road and in the subsequent treatment of sites with high crash risk or incidence (blackspots).

The importance of improved road design can be demonstrated by black spot program evaluations which show that casualty crash frequency has been reduced on average by around 25-35% across all types of treatment, and by up to 90% for the best-performed countermeasures such as roundabouts and flexible roadside barriers (e.g., Scully, Newstead, Corben & Nimmi, 2006). Evaluations of best practice infrastructure improvements typically show Benefit-to-Cost Ratios (BCR) of around five-to-one and even higher ratios for the best performing components of black spot programs.

These results show that substantial reductions in road trauma are readily achievable where design standards are improved, with the greatest gains being made where best practice is adopted. Best practice features introduced at the early design stage reduce both human and financial costs of road trauma that otherwise inevitably occur before accident black spot programs are able to detect and then address poor safety performance. Further, retro-fitting best practice designs can be costly and sometimes unaffordable, leaving road managers with little option but to reduce speed limits if improved safety is to be achieved. The trade-off between accessibility and safety then becomes a critical issue for debate and resolution.

To avoid burdening future generations with today's (or worse, growing) levels of road trauma and the associated high costs of retro-fitting safety to Australia's road network, it is essential that current design standards and practices are critically reviewed to meet Australia's road safety vision to create a truly Safe System.

3. Safe road and roadsides – designing for *Towards Zero* in Western Australia

Western Australia's *Towards Zero* road safety strategy emphasises the need for roads to be forgiving of human errors. Road and roadside design practices must be transformed to ensure that these mistakes do not result in the loss of life or long-term health. To meet this challenge using a Safe System strategy, physical design features need to be considered in conjunction with kinetic energy or, in more common terms, vehicle speeds if a truly forgiving environment is to be produced.

3.1 Main Crash Types

Roads comprise two main elements: intersections and road lengths between intersections. Analyses of Western Australia's serious casualty problem for the period 2005 to 2007 found that some 33% of serious casualties occurred at intersections, rising to 44% in metropolitan Perth (Corben, Logan, Johnston & Vulcan, 2008). A further 33% of serious casualties resulted from run-off-road crashes and in regional Western Australia, the run-off-road problem contributed almost 40% of all serious casualties.

Crash types at intersections that typically produce the most severe consequences include cross-traffic and side-impact crashes arising from turning right against on-coming traffic. At some locations, crashes involving pedestrians can be both prevalent and severe.

Along road lengths, the predominant crash types producing serious casualties are single-vehicle crashes into trees, poles, embankments and other roadside hazards, or involve over-turning. Head-on collisions also produce serious casualties, making up 8% of regional serious casualties (Corben et al., 2008). In urban settings, pedestrian collisions are also common along road lengths and in metropolitan Perth account for approximately 10% of all serious casualties.

3.2 Biomechanical Limits of Humans to Crash Violence

These dominant crash types provide initial guidance for improving road and roadside design. Our knowledge of humans' biomechanical tolerance of the forces, levels of acceleration and kinetic energy involved in key crash types also assists in designing a traffic system that minimises the loss of life and health.

Figure 1 (reproduced in Healy & Corben, 2009) shows the relationships between the risk of a fatality and impact speed in pedestrian crashes, side-impact crashes and head-on crashes, respectively. For all three crash types, the risk of a fatal outcome begins to rise rapidly when a 'threshold' impact speed is exceeded, at about: 30 km/h for pedestrian crashes, 50 km/h for side-impact collisions and 70 km/h for head-on collisions. At the higher speeds (about 65 km/h for pedestrian crashes, 85 km/h for side-impact collisions and 105 km/h for head-on collisions), death is virtually inevitable.

Figure 1: The risk of being killed as a function of impact speed for pedestrian, side-on and head-on collisions. Source: The Swedish Association of Local Authorities, (1999).

3.3 Traffic Control at Intersections in Urban and Rural Areas

The most common forms of traffic control at intersections throughout Western Australia are:

- stop or give way signs, both of which give priority to traffic on the more important of the intersecting roads. Except in local streets, the speed limits range from 60-80 km/h in urban settings and up to 110 km/h in regional and remote Western Australia;
- traffic signals, usually along urban arterial roads intersecting with other arterial roads (but sometimes with side roads of lower status). Except for Perth's CBD, the vast majority of traffic signals are situated in speed zones of 60 km/h or higher. Many signalised intersections are located on roads with speed limits as high as 80 km/h, including the outer areas of metropolitan Perth and in regional Western Australia;
- roundabouts, usually constructed where roads of similar traffic function intersect. Roundabouts are typically located in speed zones ranging from 50 to 70 km/h in urban settings and up to 80 km/h in regional and remote areas; and
- traffic regulations elsewhere, where the geometric layout of intersections determines the legal right-of-way. This applies mainly at T-intersections in local streets and on regional roads and highways, where the top of the 'T' has right-of-way over traffic using the stem of the 'T'.

For each of these situations, aspects such as the geometric layout, the standard and design of signal hardware, phasing and timing and intersection sight lines all influence safety.

3.4 Safer Intersection Design

Current intersection design usually results in vehicles on conflicting paths approaching each other at right-angles, commonly at speeds of 60 km/h or greater in urban settings and up to 110 km/h in rural and remote areas. Considering the current levels of speeding throughout Western Australia, many drivers approach at speeds higher than the set speed limits.

Right-angle collisions between two vehicles commonly result in the most severe injuries, even for vehicles with high standards of crashworthiness and even for vehicles travelling at legal speeds. The risks of severe injuries to largely unprotected pedestrians, bicyclists and motorcyclists are higher again. As noted earlier in Figure 1, injury risk rises rapidly for vehicle-to-vehicle impact speeds above 50 km/h and for vehicle-to-pedestrian (or other unprotected road users) collisions, above about 30 km/h.

Providing a high level of safety for all road users can be achieved by understanding the safety parameters and operating characteristics of all users. Issues include the physical and intellectual capabilities of children and older people, truck acceleration and braking distances and the vulnerability of cyclists, motorcyclists and pedestrians.

Against this background, there are four key principles for improving intersection safety consistent with the *Towards Zero* framework:

1. **Fewer vehicles –** by reducing the number of vehicles in use, fewer opportunities for collisions will arise;
2. **Fewer intersections –** by minimising the number of intersections within the road network and by concentrating more traffic movements at intersections with best practice safety standards, fewer opportunities for high-risk conflict will arise. (It is however necessary to

ensure that intersection reduction does not result in traffic being diverted to other intersections with lower safety standards);
3. **Fewer conflict points per intersection** – by simplifying intersections to produce fewer conflict points, the opportunities for crashes at a given intersection will fall;
4. **Impact speeds and impact angles constrained to biomechanically tolerable levels** – analysis of the kinematics of traffic collisions shows that:
   - for 90° collisions, impact (and therefore travel speeds) should not exceed 50 km/h for vehicle-to-vehicle collisions. For conflicts between vehicles and unprotected road users, impact/travel speeds should not exceed 30 km/h; and
   - for intersections located in speed limits between 50 km/h and 70 km/h, vehicle-to-vehicle conflicts must occur at angles less than 90° to ensure that the biomechanical tolerances of humans are not exceeded. Regardless of geometric layout to influence impact angles, impact/travel speeds should not exceed 30 km/h if pedestrian and cyclist risks of death are to remain below 10%.

The relationship between conflict angle and impact/travel speed at intersections if the risk of vehicle occupant death is to remain below 10%, is shown below (MUARC, 2007):

Maximum impact/travel speed	Maximum acceptable conflict angle
50	90°
60	50°/130°
70	180°
80+	None feasible

Where the required combination of speed and angle cannot be achieved, then the risk of any vehicle-to-vehicle collision must be made negligible to ensure Safe System outcomes.

While it may not always be practical to reduce the number of vehicles or the number of intersections, these options need to be considered before moving to other, often more costly options for improving intersection safety. It is also necessary as an early step to ensure that the existing design attributes (for example signing, line markings, lighting and pavement surfacing) are of the highest standards.

The four basic principles listed above have resulted in numerous specific design applications, including:

- roundabouts;
- raised platforms;
- stop-line speed humps; and
- grade-separation (bridges, for major intersections).

Further work is underway in Victoria and elsewhere to develop new designs that will satisfy the goal of assuring fundamentally low-risk intersections.

3.5 Safer General Roadway Design

Western Australia's crash patterns reveal that significant future reductions in trauma will also require a strong focus on run-off-road and head-on crashes, especially in rural areas (Corben et al., 2008). These crash types, which accounted for 38% of Western Australia's serious casualties over the period 2005-2007 (Corben et al., 2008) must therefore be comprehensively addressed if *Towards Zero* targets are to be met.

There has been an over-reliance on obstacle-free 'clear zones' to prevent life-threatening collisions with roadside hazards when drivers leave the roadway. Roadside hazards commonly include trees, poles, embankments, drains and culverts and other forms of non-traversable terrain that can lead to vehicle rollover. However clear zone standards are often impractical to provide and in many cases are opposed because of the consequent loss of valued roadside vegetation. Moreover, clear zones often offer only modest protection for vehicle occupants, even in urban areas where lower speed limits apply (Candappa, Corben and Logan, 2008). In addition, it is increasingly impractical to provide and maintain transversable terrain beside roads.

In broad terms, *Towards Zero* injury reductions can be achieved in two main ways: by upgrading road infrastructure standards or by reducing travel speeds (or by some combination of both). In practice this will require only a shift in emphasis from reliance on crash prevention to reliance on the prevention of death or serious injury resulting from crashes – a shift which has been described as 'designing the crashes' (Tingvall, 1998). It may not necessarily require additional funding – it may even be less costly – but it will require a change in organisational culture and long-standing engineering standards.

The major points of focus for Western Australia in meeting world's best practice in safety performance should therefore be on effectively managing travel speed in accordance with the standard of the road and roadside and the prevalent crash types.

The issues of 'Setting Safer Speeds' are comprehensively presented in C-MARC Fact Sheet No. 2. In short, there will be substantial safety gains from achieving at least compliance with the prevailing speed limits, due to strong, non-linear relationships between travel speed and safety: for an increase in mean travel speed of say 10 percent, the risk of fatalities rises by almost 50 percent and serious injuries by over 30 percent (Nilsson, 2004). While too broad an issue for consideration in this fact sheet, the literature also points to additional environmental gains to be garnered through reduced travel speeds.

Extensive use of continuous lengths of flexible barriers along roadsides and in medians where speed limits are 60 km/h or greater, may also dramatically reduce the severity of injuries resulting from run-off-road and head-on crashes. Flexible barriers are superior to rigid barriers in managing the exchange of energy for a vehicle that has encroached into the roadside (Tingvall, Kullgren and Ydenius, 2001) and evaluations of flexible barrier effectiveness have found reductions of around 70-80% in Victoria and up to 90% in Sweden (Candappa et al., 2009). Work carried out to protect the new railway linking Perth with Mandurah illustrates the use of continuous lengths of flexible barriers over many kilometres to provide a high level of protection for the occupants of run-off-road vehicles, as well as those who in head-on collisions. It is recommended that installation of wire barriers be based on risk assessments to determine their appropriateness.

Another option is to provide sealed road shoulders and audio-tactile line markings along unkerbed roads with comprehensive barrier protection, albeit at significant additional capital cost. While there are a number of considerations in deciding whether to seal shoulders, it is recommended that any decision should be explicitly evaluated against criteria which include:

- effect of sealed shoulders on recovery from minor lane departures, which could be especially valuable for motorcyclists;
- effect on general maintenance costs, particularly reduced barrier repair costs because of improved vehicle recovery before impact;

- opportunity for broken down vehicles to stop on a solid, level surface clear of traffic lanes.
- effect on both the capital and whole-of-life costs; and
- effect on the 'environmental footprint' of the road and roadside.

3.6 Implementation Costs and Impacts

Implementation costs are crucial in gaining the greatest return on investment in safe road infrastructure. There are advantages therefore in working with materials engineers, industry and academia in developing new, cheaper and more effective products and solutions to address the major categories of road trauma.

Wire rope barriers where applicable, have advantages in a fiscal as well as safety context. When used as an alternative to road duplication, there is no longer a need for wide road reserves: only a median width of less than two metres is required for flexible barriers to provide a high level of protection against head-on collisions. There is also no longer a need for clear zones of around 10 metres which even when achievable offer at best, modest levels of protection in run-off-road events. There are clear financial and environmental savings from this general strategy. For major intersections otherwise requiring grade-separation for example, highway infrastructure requirements such as bridge deck dimensions and associated structural strength are substantially reduced and the need for wide roadsides clear of vegetation is removed. Both the capital cost and the long-term environmental footprint of the highway are markedly reduced.

4. Summary and conclusions

Designing for safer roads and roadsides within a Safe System framework is challenging but achievable. *Towards Zero* represents an opportunity for a shift in thinking to implement new, safe design and operational standards for Western Australia’s roads. These standards do not need radically new design features but rather a change in the circumstances and extent to which current approaches and measures are used in future. On less significant roads, where high levels of investment to retro-fit safety cannot be justified, the potential for lower speed limits must be considered to reflect the lower inherent quality of roads and roadsides. Running a series of demonstration projects represents one way to engender quick support for this shift in approach.

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Acknowledgement

This fact sheet has been produced with funding from the Road Safety Council in the interest of saving lives on our roads.

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