# Speed limit setting and the Safe System principle

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**Abstract**

The Safe System policy dictates that speed limits for the road and traffic system use human biomechanical and human competency as the design parameter to set the values. Taking crash injury severity factors into account research into the physics of crashes has determined when the physical forces will be too great for the human body to tolerate. Despite the formal adoption of the Safe System principles by all Australian Governments in 2004, no Australian State has adopted recommended Safe System speed limits. While most Australian States are not yet fully applying Safe System principles to speed zoning, this paper analyses New South Wales practices as an example. The current NSW Speed Zoning Guidelines, while transitionally moving towards a Safe System approach, explicitly aim to guide the setting of speed limits to "ensure that they are practical and balance mobility, road safety and community concerns." Part of the problem for governments introducing safe speed limits is the amount of vocal opposition to lowering the limits. This paper identifies a number of specific departures from the Safe System approach inherent in the setting of speed limits as well as some of the ways that community attitudes might be shifted to promote better acceptance of safer speeds.

## Introduction

Australian Governments adopted the Safe System approach to underpin all State and National road safety strategies from the year 2004 onwards. Speed management is an essential component of any road safety strategy that aims to reduce or eliminate road deaths and injury. The speed that vehicles travel on roads, along with the road condition, predicts the likelihood and severity of crashes. The Safe System approach requires the road traffic management system to limit speeds to survivable levels, taking into account human fallibilities and frailties. That is, the design parameter is human tolerance to physical force in a crash as well as the limits to human reaction time to respond to unexpected changes in the road environment.

Generally, the speed zoning across all Australian States and Territories does not comply with Safe System parameters. The reasons for this are political and efforts by the Road Authorities to do this are hampered by perceived resistance by Australian drivers. Survival speeds are well known and scientifically established over the past 50 years or so (Grzebieta, Rechnitzer, & McIntosh, 2013). We know what the Safe System speed limits are. They are just not being implemented.

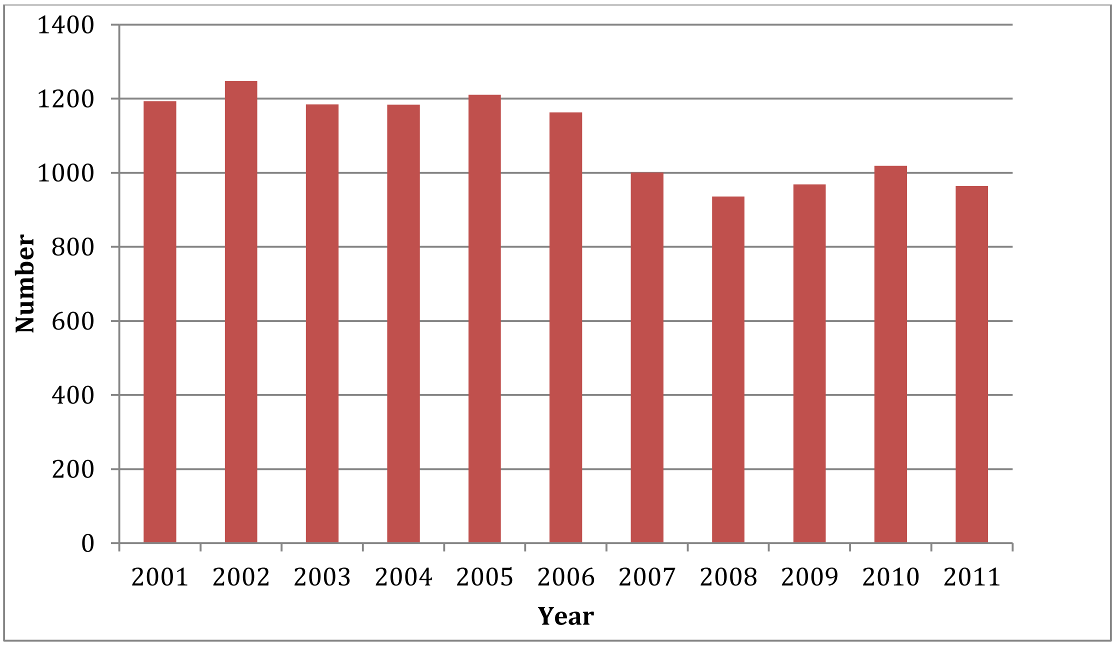
Under the heading "Risk Taking Behaviours", the NSW Government reported, in the current NSW Road Safety Strategy 2012-2021, "during the three year period 2008 to 2010, excessive or inappropriate speeding accounted for 42 per cent of all fatalities[1]." From 2001 to 2011, there were 68,383 individuals identified in the linked NSW CrashLink-APDC[2] data extract

[1] http://roadsafety.transport.nsw.gov.au/downloads/road_safety_strategy.pdf

[2] Transport and Road Safety (TARS) Research has predominantly utilised linked police-reported road crash (provided in Transport for NSW's CrashLink) and hospital-related data (provided in the NSW Ministry of Health's Admitted Patient Data Collection i.e. APDC) to examine various aspects of hospitalised injury following road traffic crashes in NSW.

who were hospitalised and information on their crash was recorded in CrashLink. Speed was identified as a contributing factor for 12,073 (26.2%) motor vehicle occupants who were hospitalised following their injury (Figure 1). It should be noted that during 2001-2011, there were also 51,570 individuals who were hospitalised following a road traffic crash where their hospital record did not link to CrashLink and no information on the contribution of speed to the crash was available (Mitchell, Bambach, Williamson, & Grzebieta, 2013). However, to the extent that injuries are incurred only when the vehicle speed on impact exceeds the physical tolerance of the human body, speed is in fact involved in all injury crashes.

***Figure 1: Number of hospitalised road trauma of motor vehicle occupants in NSW where speed was identified as a contributing factor by year, CrashLink-APDC, 2001-2011[1]***




[1] Speed was identified for at least one vehicle controller involved in the crash, but may not necessarily apply to the vehicle where an individual was hospitalised for their injury.

The analysis of these data found that vehicle occupants in speed related crashes are 2.7 times more likely to die if they are injured compared with vehicle occupant casualties where speeding was not a factor; and motorcyclists who are injured in a speed related crash are 6.7 times more likely to die compared with being injured in a crash where speeding is not involved.

**NSW Speed Zoning Guidelines**

The present analysis of NSW is not because the state is doing badly on speed limit setting compared with other state and territories. On the contrary, NSW has speed limits that are closer to Safe System principles than many other jurisdictions of Australia. Thus it is worthwhile to consider how one of the better states is doing vis-a-vis Safe System speed limits. In addition, NSW has a guideline document on speed limit setting.

The NSW Speed Zoning Guidelines explicitly aim to guide the setting of speed limits to “ensure that they are practical and balance mobility, road safety and community concerns.” This principle of “balance” means that the Guidelines, in effect, permit safety to be traded for the sake of travel efficiency and community views. In other words, it is not consistent with a Safe System approach that places absolute priority on safety over all other road travel objectives.

Where there is a possibility of head on crashes the speed limit should be no greater than 70 km/h (Tingvall & Haworth, 1999). However, Figure 2 was copied out of the NSW Speed Zoning Guidelines.

***Figure 2: Rural undivided road with sealed pavement greater than 5.6 metres (Source: NSW Speed Zoning Guidelines, page 26)***


This is clearly not consistent with a Safe System policy. There is every chance of a head-on collision, and yet this photo is promoting a very high speed limit for these conditions.

By way of contrast the road seen in Figure 3 is limited to a top speed of 80 km/h.

***Figure 3: Safe System speed limit of 80 km/h in New Zealand (photo by S Job)***

There is scant mention of any limits lower than 50 km/h. This suggests that limits lower than this are discouraged, apart from the 40 km/h school zones. The 40 km/h speed limit first appears in a table entitled “Special Speed Limits…” suggesting that this is a limit that is used only in special circumstances.

On page 28 there is a small paragraph advising that 40 km/h limits are “used in areas where vulnerable road users are present”. At 40 km/h there is a 40% that a pedestrian would die if hit by a car; then it doubles to over 80% chance of death at 50 km/h. Using 40 km/h speed limits, or lower, in areas where vulnerable road users would be mandated under a *safe system.*

It is noted, however, that the NSW Roads Minister, Duncan Gay has recently announced that the Sydney Central Business District will soon have a 40 km/h speed limit – a step in the right direction. However, as early as 1986 researchers found that the risk of death to pedestrians rises exponentially with increases above 30 km/h. See Figure 4.

***Figure 4 Probability of a fatal injury for a pedestrian in a vehicle crash***
*Source: Speed Management, (ECMT, 2006)*

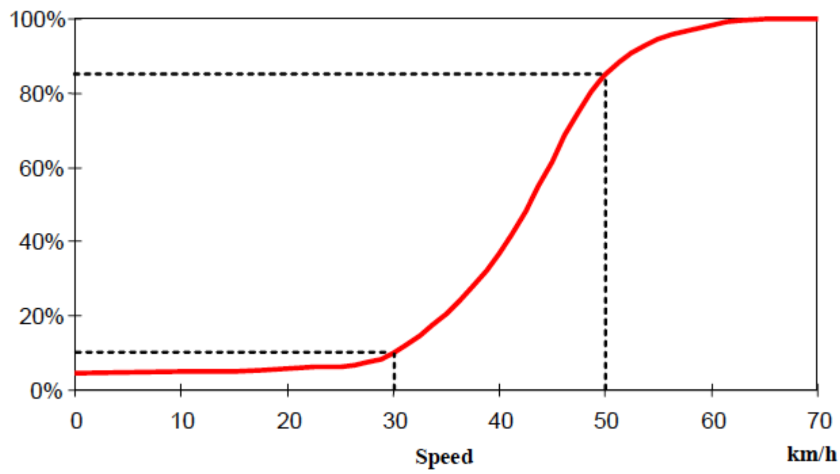



Figure 5 is clearly a picture of a residential street, yet it suggests that the speed limit should be set at 50 km/h – well above the survival threshold for vulnerable road users like pedestrians and cyclists. Moreover, at night where street lighting is very poor, drivers have to rely on their vehicle's headlights, which in an urban environment are set to low beam. This too often results in drivers being not capable of seeing pedestrians until they have struck them if traveling at 50 km/h (Grzebieta et al., 2009). A similar road in many European jurisdictions would have speed limits of 30 km/h or in some cases even 20km/h so that vehicles (night or day) will either stop in time or, if they do collide with a pedestrian, the injury will be survivable.

***Figure 5: 50 km/h default urban speed limit***
***(Source: NSW Speed Zoning Guidelines, page 24)***

Again, this example could send misleading messages to the users of these Guidelines in road safety terms. According to Wramborg (2005), at 50 km/h a pedestrian would have less than a 20% chance of surviving a crash with a motor vehicle on this road.

Under the heading of Section 2.3 of the NSW Speed Zoning Guidelines, "Key factors in setting speed limits", it says, "The fundamental principle in setting speed limits for a particular length of road is that the established speed limit should reflect the road safety risk to the road users while maintaining mobility and amenity." This could be interpreted to mean that mobility should be kept constant while considering safety risks.

Finally, the NSW Speed Zoning Guidelines make no mention of the importance of giving motorists visual cues about the expected maximum speeds that they should travel at. For example, where there is high pedestrian activity, the lanes or roads should have perceptual or physical features that would effectively make drivers uncomfortable if they were to exceed 30-40 km/h. Instead there is a heavy reliance on signs and markings to tell drivers what the legal limits are.

The NSW Speed Zoning Guidelines prescribe a 10-step process for reviewing speed limits, including crash analyses, site inspections, speed surveys and internal and external consultation with stakeholders. The introduction to this process again highlights the need to "balance safety with the mobility needs of the community" and the need to consider community views. This could be interpreted to mean that weighting is given to road users' desires over road user safety.

Currently, there is a push by some vocal community leaders to allow higher speeds, such as the Liberal Democratic Party's campaign[3] to let motorists decide what the speed limit should be. Indeed, the Northern Territory Government has recently introduced a 12-month trial of open speeds on 200 kilometres of the Sturt Highway. The idea is to let motorists choose the speed limit by way of identifying the 85$^{th}$ percentile of speeds travelled during the trial. The Chief Executive Officer of the International Road Assessment Program (iRAP) has written to the responsible Minister and advised of his estimate of 20 people being likely to be killed or injured over the next 10 years as a direct result of this trial. A collection of road safety experts, medical and emergency response practitioners, police and community organisations have argued the trial is irresponsible and dangerous[4].

There is a wealth of research showing that humans are ill equipped to judge risks such as road travel risks (Job, Sakashita, Mooren, & Grzebieta, 2013; Wilde, 1994). Moreover, there is a phenomenon called "evolution of speed" whereby 85$^{th}$ percentile travel speeds drift up over time (Hauer, 2009). This occurs when speed limits are set using the 85th percentile method for three possible reasons:

1. Typically half of the drivers tend to drive above the speed limit which gradually pushes the 85th percentile speed up over time;
2. Many drivers seek to drive faster than the average speed in effort to self affirm their image of better than average drivers; and
3. As wider lanes become more prevalent the average speed on roads increases.

[3] See http://aca.ninemsn.com.au/article/8787201/speed-limits-liberal-democratisation

[4] See http://www.abc.net.au/news/2014-02-01/speed-limits-shelved-for-nt-highway-sports-cars/5232388

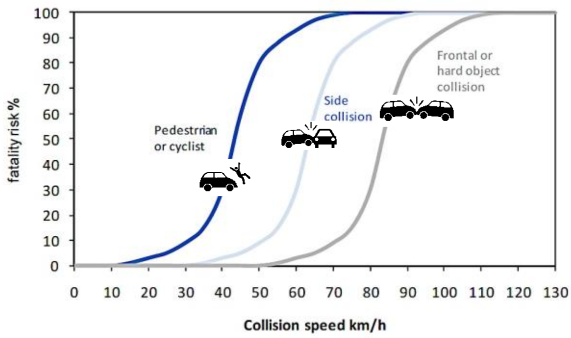
In addition, there is an abundance of evidence of direct links between speed limit raising /lowering and road casualties. A clear example of this is when the State of Victoria raised their rural and outer Melbourne freeway speed limits from 100 km/h to 110 km/h in 1987 producing an increase in casualties of nearly 25%. After the speed limits were reduced on these roads, back to 100 km/h, road casualties fell by 19% (Sliogeris, 1992).

After the National Maximum Speed Limit (NMSL) 55 mph in the US was introduced in 1974, road fatalities dropped by over 16%, saving 8,856 Americans' lives. Moreover, the repeal of the NMSL resulted in at least 17% more road deaths in the States that raised the maximum speed limit to 65 mph, adjusting for miles travelled (Farmer, Retting, & Lund, 1999).

**Safe System Speed Limits**

The Safe System policy dictates that speed limits for the road and traffic system use human biomechanical and human competency as the design parameter to set the values. Taking crash injury severity factors into account research into the physics of crashes has determined when the physical forces will be too large for the human body to survive (Grzebieta et al., 2013). Biomechanical limits have been calculated. (See Figure 6.)

***Figure 6: Fatality risk curve Source: (Wramborg, 2005)***




Given the fatality risks for various types of crashes, example maximum speed limits for a Safe System are indicated in Table 1 below.

***Table 1: Safe System maximum vehicle speeds related to the infrastructure assuming safest vehicle designs and 100% restraint use (Source: (Tingvall & Haworth, 1999))***

| Type of infrastructure and traffic | Possible travel speed (km/h) |
|---|---|
| Locations with possible conflicts between pedestrians and cars | 30 |
| Intersections with possible side impacts between cars | 50 |
| Roads with possible frontal impacts between cars | 70 |
| Roads with no possibility of a side impact or frontal impact (only impact with the infrastructure) | 100+ |

Speed limits for preventing fatalities takes into account the known fatality risk levels for each type of potential collision when applying a safe system approach. An OECD guidance document on the Safe System approach emphasises the need for very low speed limits – no greater than 30 km/h – where conflicts with pedestrians are possible (OECD, 2008). This would mean that virtually all residential areas and shopping precincts should be zoned at 30 km/h or lower. Indeed, the Dutch experience of introducing 30 km/h zones was nearly a 70% drop in road casualties across the collective length of these zones in 2002 (Wegman, 2005).

As speed increases, both the incidence and severity of road injury also increase. Even occupants of motor vehicles face a sharp rise in fatality risk when speeds exceed 40 km/h if the vehicle crashes into a rigid object, such as a tree or pole (Archer, Fotheringham, Symmons, & Corben, 2008). The setting of maximum speed limits must place road user safety as the highest priority criteria. While roads are built for mobility – and not for safety – a broader perspective may help to achieve improvements to both objectives.

**International knowledge and good practice**

A Safe System approach to speed limit setting takes into account the threshold of physical resistance of the human body to the energy released during a crash (which is related to the impact speed) when assessing an appropriate speed. Yet while the World Health Organisation (Peden, 2004) has reported that pedestrians incur a risk of around 80% of being killed at an impact speed of 50 km/h, while this risk is reduced to 10% at a 30 km/h impact speed, most urban centres in Australia have general speed limits of 50 km/h or 60 km/h. Some research indicates that the fatality risk may be much lower than earlier research found; nevertheless, this research found that the fatality risk for pedestrians being hit at 50 km/h is double that of being hit at 40 km/h and five times as great as being hit at 30 km/h (Rosen & Sander, 2009).

The review of speed limits ought to be consistent with the Government's policy of Safe System road safety. Australian consultant, Eric Howard, led a project to develop guidance book on speed management for the OECD (OECD, 2006). Using a set of objective criteria, a template for speed limit decision-making was included. This takes into account the intended function of the road, environmental sustainability, land use and resident comfort, mobility and safety. The recent WHO Pedestrian Safety Manual (Bartolomeos et al., 2013) also highlights the need for lower speeds for pedestrian safety.

In addition, the Global Road Safety Partnership produced a speed management manual two years later (Howard, Mooren, Nilsson, Quimby, & Vadeby, 2008). It advises that according to Safe System principles setting speed limits should take into account the following factors.

- If there are large numbers of vulnerable road users on a section of road they should not be exposed to motorised vehicles travelling at speeds exceeding 30 km/h.
- Car occupants should not be exposed to other motorised vehicles at intersections where right angle, side-impact crashes are possible at speeds exceeding 50 km/h.
- Car occupants should not be exposed to oncoming traffic where their speed and that of the traffic travelling towards them, in each instance, exceeds 70 km/h, and there are no separating barriers between opposing flows.
- Moreover, if there are unshielded poles or other roadside hazards that represent a hard impact, the speed limits need to be reduced to 50 km/h or less.

With regards to rural safety, the Swedes have been particularly successful in re-fitting the rural road highway network with movable barrier systems they call 2+1. This enables the same road space to accommodate high speeds without compromising safety. See Figure 6 for to view an image of this design.

**Figure 6: 2+1 Road Barrier on rural Swedish Highway (photo by Roger Johansson)**

This road barrier system was first installed in 1998. There are now 1700 kilometres of road with this treatment, that has reduced up to 90% of fatalities on these roads (R. Johansson, 2009).

In Switzerland and other European countries, speed limits where pedestrians may be exposed have speed limits of 20 and 30 km/h. Figure 7 provides an example of a Swiss road engineered to keep motor vehicles from exceeding the 20 km/h limit.

***Figure 7: Swiss road with 20 km/h speed limit (photo by S. Job)***


The Sustainable Safety approach taken in The Netherlands is an earlier version of the Safe System policy. This approach was introduced in the early 1990s with recognition that human road users are fallible, but that human life can be sustained if a road traffic system can be made inherently safe. The three design principles for road networks that underpin the Sustainable Safety vision are: functionality, homogeneity and predictability (Wegman, 2005). From the beginning of implementation of this road safety approach, roads were categorised into three basic functions: through-roads, distributor roads and access roads. Roads in each of these categories were designed to facilitate homogeneity of road use within them, thus enhancing the predictability of the system. However, it is important for road users to easily understand the behaviour that is expected of them based on what they perceive the intended function to be. In other words roads should be “self-explaining”, or such that the traffic environment “elicits safe behaviour simply by its design (Jan Theeuwes & Godthelp, 1995).”

Beyond signs and pavement markings, roads should have "essential recognisability characteristics" that will send to road users strong messages about how the road should be used, including the selection of travel speed (Stelling-Konczak, Aarts, Duivenvoorden, & Goldenbeld, 2011). The Dutch now have a lot of experience in designing self-explaining roads (SER) instead of only relying on regulatory mechanisms such as speed limit signs and enforcement to encourage safe speeds of motor vehicles.

New Zealand also successfully embarked on the SER approach. In 2004 a National Speed Management Initiative was launched. Describing this initiative, the New Zealand Ministry of Transport advised that *"The emphasis is not just on speed limit enforcement, it includes perceptual measures that influence the speed that a driver feels is appropriate for the section of road upon which the are driving – in effect the self-explaining road (New Zealand Ministry of Transport, 2004)."*

***Figures 8a & 8b: Shared zone and self-explaining urban road***

One definition of "self-explaining roads" is "A road and traffic environment that naturally elicits speeds that are within the human tolerances for serious injury through the relevant conflict points and contributes to effective transport operations.[5]"

In New Zealand, there has been a concerted move to design roads and streets in a way that effectively modifies road user behaviour to be more consistent with the primary function of the roads. A study using video data collection and analysis found that self-explaining roads (SER) treatments achieved a significant shift in the way people used the roads (Mackie, Charlton, Baas, & Villasenor, 2013). For example, there was a 30% decrease in motor vehicle traffic and a 17% increase in pedestrian counts at sites where roads had been redesigned. Moreover, preliminary crash data indicated that the SER project achieved a 30% reduction in crashes and an 86% reduction in crash costs per annum since implementation of these designs.

The United Kingdom, like the Netherlands, is in the top best performing countries in terms of road fatality rates. They recognise the need to keep motorised traffic speeds very low to ensure that pedestrians can use the road without being maimed. In a car to pedestrian crash at 25 km/hour most pedestrians would live; whereas in similar crash where the vehicle is traveling at 50 km/h the pedestrian would die. In Sweden, the road administration has taken speed limits and infrastructure redesign quite seriously. Where vulnerable road users are present road lanes for cars and buses are narrowed. Applying the road design shown in Figure 9 is thought to reduce fatalities by 80-90% (Roger Johansson, 2009).

[5] Brendan Marsh, Linked-in Road Safety Professionals discussion blog November, 2012.

*Figure 9: Local street in Borlange, Sweden (Source: Johansson, 2009)*

However, the most dramatic drop in speeds occurred on New Zealand roads after they applied self-explaining roads redesigns (J. Theeuwes, Van der Horst, & Kuiken, 2012). A study found that there was "a significant reduction in vehicle speeds on local roads and increased homogeneity of speeds on both local and collector roads" (Charlton et al., 2010).

## Conclusions

The NSW Speed Zoning Guidelines currently do not place sufficient priority on safety. Australian road and traffic planners should consider categorising roads into functional hierarchies and look at ways to make traffic more homogeneous and predictable. The New Zealand approach to implementing self-explaining roads should be examined for applicability in Australia. Perceptual and other engineering treatments, especially at gateways to speed limit changes, should be more fully researched and considered by Australian road authorities (including local governments).

Setting speed limits based on the 85th percentile of free travel speeds is irresponsible and dangerous.

The revision of the NSW Speed Zoning Guidelines should take into account best European practices and Safe System principles.

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