

MUARC ECIS Fact Sheet 1: Achieving Vision Zero through the Safe System - Insights from the Enhanced Crash Investigation Study (ECIS)¹

The Vision Zero concept and the Safe System

Implemented first in Sweden (1997), *Vision Zero* is an approach to road safety that rests on the principle that no person should be seriously injured or killed when using the road transport system.

Vision Zero places distinct responsibilities on designers, operators, and users of the road transport system to ensure safety, and that the goal of eliminating serious injury is realised.

Consistent with *Vision Zero*, the *Safe System* approach is a powerful advocacy framework and model to understand and address the key risks within the road transport system.

Principles of Vision Zero

- Loss of health and life is an unacceptable trade-off for the ideal of unfettered mobility.
- Mobility ought to be a function of the level of in-built safety of the road transport system.
- Humans are fallible and prone to error.
- The human body has a limited ability to withstand the forces of a crash without being injured.
- To protect road users from injury, the system must be built around the physical tolerance of the human body to crash forces.

A model to achieve Vision Zero

The *Vision Zero Model of Safe Travel*² provides the basis for understanding how the elements of the road transport system interact and how an inherently safe system will prevent road users involved in a crash from being seriously injured.

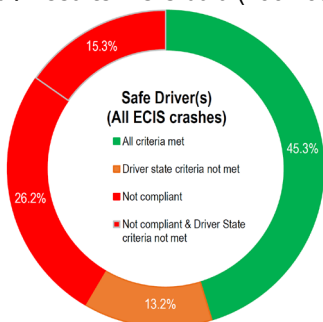
The *Vision Zero* model states that the level of injury sustained in a crash is a consequence of impact speed and the level of safety provided by the vehicle and the road infrastructure.

Due to the relationships between the speed limit, driver speed choice and speed at impact, the speed limit is the critical regulator of the overall safety of the system (see *Fact Sheet 2*).

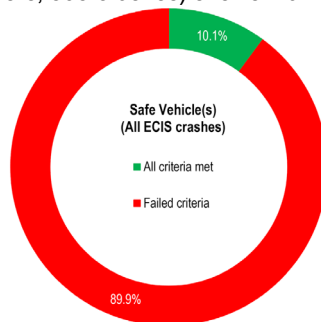
The *Vision Zero* model asserts that once all *Safe Driver*, *Safe Vehicle*, and *Safe Roads* criteria are met, the road transport system is 'inherently safe,' and no-one would be seriously injured (defined as MAIS 3+ severity level) were a crash to occur.

The *Safe Driver* criteria are the minimum expectations of the driver; once met, drivers can reasonably expect that the system is designed and operated to protect all system users from serious injury when other events, such as errors, occur.

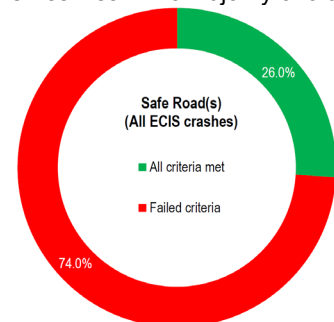
Data / Results: ECIS data (400 hospitalised drivers, 393 crashes) shows that the criteria **were not met** in the majority of crashes.



Criteria (driver compliance): seatbelt worn, within speed limit, BAC within legal limit, no illicit drugs, not handling mobile phone. Criteria (driver state): not excessively drowsy; no misuse/abuse prescription medication)



Criteria: Vehicle has 5-star ANCAP safety rating, frontal and side airbags fitted; Electronic Stability Control (ESC) fitted



Criteria: Speed limit defined according to crash type (head-on, run-off-road, across path/side impact, rear impact) and available road infrastructure.

What does ECIS tell us about the performance of the road transport system?

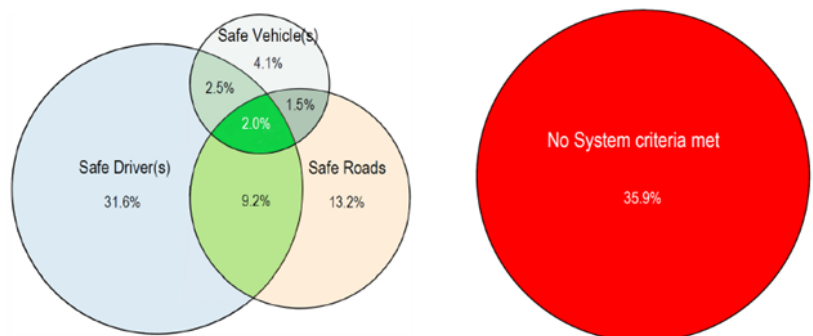
One or more of the *Safe Driver*, *Safe Vehicle*, and *Safe Roads* criteria were met in 64.1% of ECIS crashes.

Drivers meeting the *Safe Driver* criteria (e.g., compliant with speed limit) were largely unsupported by *Safe Vehicles* (e.g., driving a 3-star vehicle) and/or *Safe Roads* (no centre barrier), as shown in Venn diagram

None of the *Safe Driver*, *Safe Vehicle*, and *Safe Roads* criteria were met in 35.9% of crashes.

Consistent with the *Vision Zero* model, in crashes (2%) where all criteria were met, no driver sustained an MAIS 3+ (serious) injury.

Venn diagram (below) showing the percent of crashes where the *Safe Driver*, *Safe Vehicle*, and *Safe Roads* criteria were met (and overlap), and not met.



Implications – Substantial opportunity exists to improve the safety of Victoria's road transport system and prevent many drivers being seriously injured in a crash. Improved vehicle safety, matching speed limits to surrounding infrastructure and the safety of the vehicle fleet, installing safe road infrastructure, and improved driver compliance will all play a role in achieving *Vision Zero*.

1 Fitzharris, M, Lenné, MG, Corben, B, Pok Arundell, T, Peiris, S, Liu, S, Stephens, A, Fitzgerald, M, Judson, R, Bowman, D, Gabler, C, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 1: Overview and Analysis of Crash Types, Injury Outcomes and Contributing Factors. Melbourne Vic Australia: Monash University, 2020. <https://www.monash.edu/muarc/ecis>
 2 Tingvall C, Lie A, Johansson R. Traffic Safety in Planning - A Multidimensional Model for the Zero Vision. In: von Holst H, Nygren A, Andersson AE, editors. Transportation, Traffic Safety and Health — Man and Machine: Second International Conference. Brussels, Belgium: Springer Berlin Heidelberg; 1996. Published 2000. p. 61-9.

MUARC ECIS Fact Sheet 2: The regulating role of speed in determining the safety of the road transport system^{1, 2}

Speed is central to Vision Zero and the Safe System approach

The foundational principle of *Vision Zero* is that no person should be seriously injured when using the road transport system.

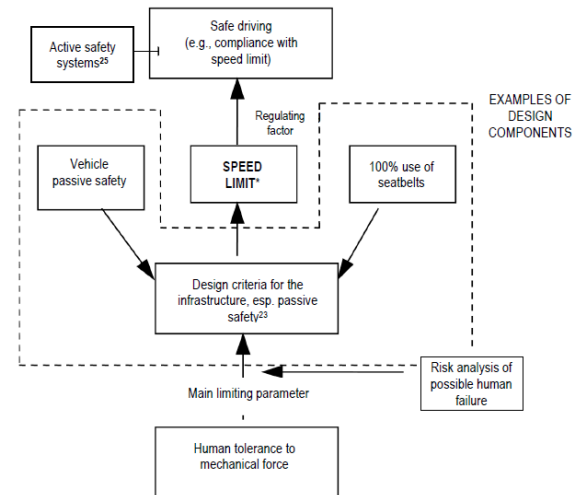
Per the *Vision Zero Model of Safe Travel* (see diagram), human tolerance to mechanical force is the main limiting parameter around which the road transport system must be designed and operated.

For injury to be avoided, the criteria for a *Safe Driver*, a *Safe Vehicle* and *Safe Roads* must be set in such a way that were a crash to occur, the level of force the driver is exposed to is limited, and then managed, by the design components of the system (per panel on right).

The speed limit is the overarching design parameter that *regulates* the inherent safety of the road transport system. In the *Vision Zero Model of Safe Travel*, the speed limit is set in accordance with the road infrastructure and the safety offered by vehicles (see diagram).*

The speed limit is then directly – or indirectly through impact speed – embedded in the *Safe Driver*, *Safe Vehicle* and *Safe Roads* elements of the system (see Fact Sheet 1).

The Vision Zero Model of Safe Travel^{2 3}



Data: The ECIS database consisted of data from 400 hospitalised drivers injured in crashes (case) and 1,942 non-crash-involved drivers (control) whose travel speed was measured at 172 locations where an ECIS-studied crash occurred.

That speed is a regulator of the safety of the road transport system rests on three relationships, as shown by:

1. Travel speed is highly correlated with the speed limit

High correlation ($r = 0.74$, $p < 0.05$) between driver speed choice and the speed limit. The mean and median travel speed were at, or slightly below, the speed limit in all speed zones (50 km/h to 110 km/h zones included).

Across all speed zones, 15% of drivers were exceeding the speed limit by 3 km/h or more. This included data from 2,180 drivers where travel speed was known.²

2. Vehicle speed at impact is highly correlated with travel speed

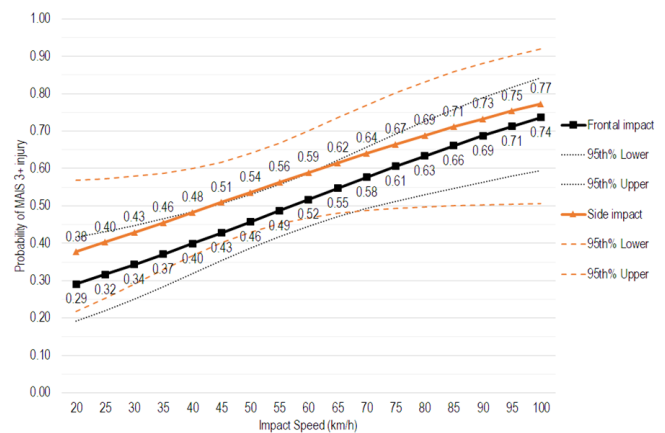
Very high correlation ($r = 0.86$, $p < 0.05$) in crashes where no pre-crash braking was seen (45.5% of crashes).

Less than a third (-31%) of travel speed was 'wiped off' due to short braking time (1.3 s on average).

In crashes where braking occurred (54.5% of crashes), braking modified the relationship between travel speed and the speed at impact, but the correlation remained high ($r = 0.67$, $p < 0.05$).

3. Impact speed is directly related to injury severity

Higher probability of MAIS 3+ injury at higher impact speeds for drivers involved in frontal and side impact crashes.

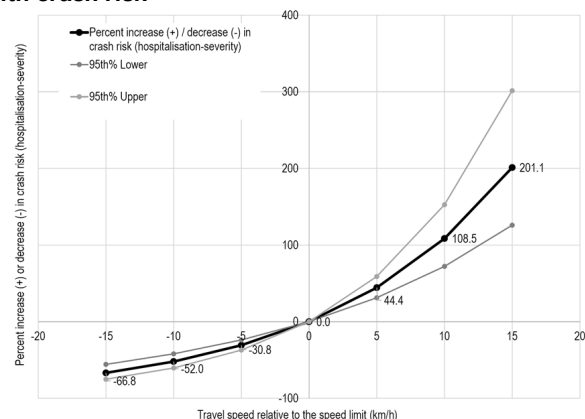


Driver speed choice relative to the speed limit was associated with crash risk

Travelling 5 km/h above the speed limit was associated with a 44% increase in crash risk (RR: 1.44, 95% CI: 1.31–1.59) while driving 10 km/h above the speed limit more than doubled the crash risk of drivers travelling at the speed limit (+108.5%; RR: 2.09, 95% CI: 1.72–2.53).

Travelling below the speed limit had a protective effect for crash involvement, e.g., driving 5 km/h below the speed limit was associated with a 30.8% lower risk of involvement in a hospitalisation severity crash (RR: 0.69, 95% CI: 0.63–0.76).

Exceeding the speed limit was found to be a contributing factor for 26.2% of all crashes and 36.6% of MAIS 3+ injury severity crashes (per ECIS Report 1), with this being higher for drivers involved in Lane Departure crashes.



Implications – ECIS demonstrates the central regulating role that speed limits play in determining crash and injury risk.

Reductions in the number of drivers seriously injured can be achieved through lower impact speeds, with a 10 km/h lower impact speed translating to 12.3% fewer drivers sustaining MAIS 3+ severity injuries. Without any change, a 7.9% reduction in hospitalisation crashes can be achieved through 100% driver compliance with the speed limit. This reduction can be even higher by ensuring high levels of driver compliance with speed limits set in accordance with the *Safe Roads* criteria (see Fact Sheet 1).

1 Fitzharris, M, Lenné, MG, Corben, B, Pok Arundell, T, Peiris, S, Liu, S, Stephens, A, Fitzgerald, M, Judson, R, Bowman, D, Gabler, C, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 1: Overview and Analysis of Crash Types, Injury Outcomes and Contributing Factors. Melbourne Vic Australia: Monash University, 2020. <https://www.monash.edu/muarc/ecis>
 2 Fitzharris, M, Corben, B, Lenné, MG, Peiris, S, Pok Arundell, T, Liu, S, Stephens, A, Bowman, D, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 2: Speed, crash risk and injury severity. Melbourne Vic Australia: Monash University, 2022. <https://www.monash.edu/muarc/ecis>
 3 Tingvall C, Lie A, Johansson R. Traffic Safety in Planning - A Multidimensional Model for the Zero Vision. In: von Holst H, Nygren Å, Andersson ÅE, editors. Transportation, Traffic Safety and Health – Man and Machine: Second International Conference. Brussels, Belgium: Springer Berlin Heidelberg; 1996. Published 2000. p. 61-9.

MUARC ECIS Fact Sheet 3: Vehicle safety, speed, and injury severity^{1 2}

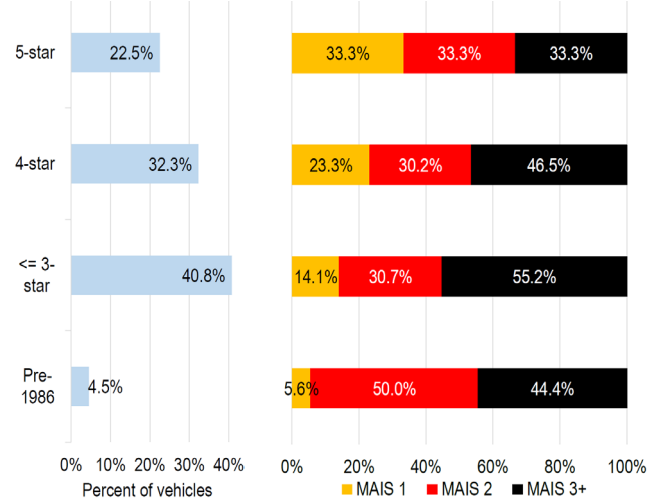
Safe Vehicles are integral to eliminating serious injury

Vehicles differ in their capability to protect drivers from injury in the event of a crash. Vehicle safety ratings, such as the ANCAP star-ratings, provide an index of this level of safety.

The ECIS data highlight the crucial role that vehicles play in protecting occupants from injury. Relatively fewer drivers in 5-star rated vehicles sustained MAIS 3+ (serious and higher) severity injuries compared to drivers in cars with lower safety star ratings.

Impact speeds based on crash type (head-on, side impact, rear impact), collision object, and ANCAP vehicle safety ratings were used to determine whether the impact speed estimated through crash reconstruction was within or exceeded the engineered-in safety (i.e., safety envelope) of the vehicle (see ECIS Report 1).

For 41.7% of crash-involved drivers of 5-star safety rated vehicles, the impact speed was higher than the speed at which the vehicle could protect occupants from serious injury.



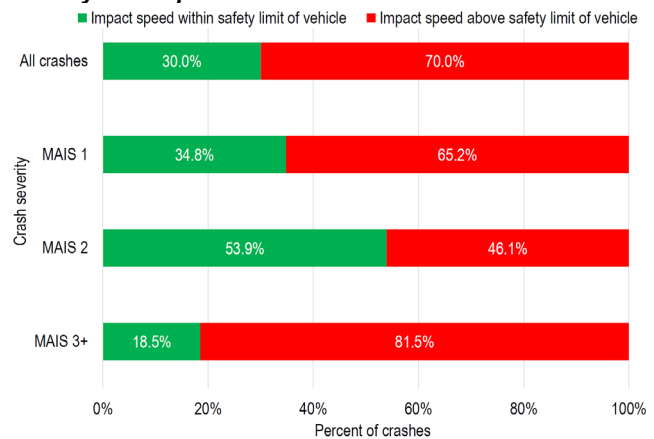
Injury severity is higher when the impact speed is greater than the safety envelope of the vehicle

The ECIS data show that in 70% of crashes the speed at impact exceeds the safety envelope of the vehicle based on its safety rating, crash type and collision partner / impact object.

The proportion of crashes where the impact speed was above the safety envelope was higher for Lane Departure crashes (78.9%) compared to Across Path crashes (62.4%) and Rear Impact crashes (57.4%). This aligns with the higher injury severity of these crashes.

There is a clear link between impact speed exceeding the in-built protection capability of the vehicle and injury severity.

The proportion of crashes where the impact speed was outside of the safety envelope of the vehicle(s) was highest for those where MAIS 3+ injuries were sustained (81.5%) compared to MAIS 2 (moderate) (46.1%) and MAIS 1 (minor) severity injuries (65.2%).



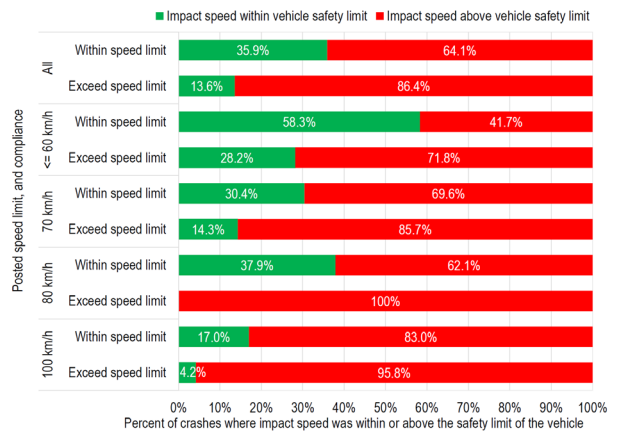
The link between speed limits, speed limit compliance, impact speed and the vehicle

The proportion of crashes that occurred at impact speeds within the engineered-in safety limit of the car was higher (35.9%) where the involved driver(s) was complying with the speed limit prior to the crash, compared to where an involved driver had been exceeding the speed limit (13.6%).

Exceeding the speed limit was associated with 3.6 times higher odds of the crash impact speed being beyond the point where the vehicle can protect the driver and occupants from serious injury.

The percentage of crashes that occur at speeds above the safety envelope of the vehicle increases with each higher speed zone.

Key point: even for drivers compliant with the speed limit, crashes occurred at impact speeds where the safety measures of even the safest vehicle cannot protect drivers from serious injury. Exceeding the speed limit further inflates this high risk.



Implications

The ECIS findings highlight the fundamental mismatch between current speed limits and the ability of vehicles to protect drivers from serious injury. This includes modern, 5-star safety rated vehicles.

Lowering speed limits to match the level of protection in the road environment and the safety offered by vehicles given foreseeable crash types would be highly effective in addressing this risk factor. Ensuring driver compliance with these speed limits would ensure optimal reductions in serious injuries could be achieved.

While reductions in serious injury occur as the proportion of 5-star safety rated vehicles increase in the fleet, the magnitude of this reduction will be constrained by the high impact speeds that occur on high-speed roads.

Advanced vehicle technology, including Intelligent Speed Assist (ISA) will act to ensure speed limit compliance, while Autonomous Emergency Braking (AEB) will assist crash prevention and reducing impact speed. However, given technology fitment and current fleet turnover rates, full fleet penetration of these technologies will take 25 years to occur.

Given the long-lead times in the availability of advanced safety technology across the vehicle fleet, the use of speed limit reductions as a means of ensuring driver safety represents the single most cost-effective population-based countermeasure available to reduce the incidence of serious injury in crashes.

Speed limit reductions are especially important on roads where *Safe Roads* infrastructure is cost-prohibitive, and as an interim countermeasure to ensure safety.

1 Fitzharris, M, Lenné, MG, Corben, B, Pok Arundell, T, Peiris, S, Liu, S, Stephens, A, Fitzgerald, M, Judson, R, Bowman, D, Gabler, C, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 1: Overview and Analysis of Crash Types, Injury Outcomes and Contributing Factors. Melbourne Vic Australia: Monash University, 2020. <https://www.monash.edu/muarc/ecis>
 2 Fitzharris, M, Corben, B, Lenné, MG, Peiris, S, Pok Arundell, T, Liu, S, Stephens, A, Bowman, D, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 2: Speed, crash risk and injury severity. Melbourne Vic Australia: Monash University, 2022. <https://www.monash.edu/muarc/ecis>

MUARC ECIS Fact Sheet 4: Error and safety by design¹

Safety by design: the role of road infrastructure in shaping driver behaviour

Driver error is a common driver performance failure and occurs due to driver, vehicle, and environmental influences. *Vision Zero* and the *Safe System* approach state that the road transport system needs to be designed and operated to support driver decisions and to be forgiving of error in the event of a crash.

Driver error was seen to have been a contributing factor in 59.5% of ECIS crashes. Other co-occurring contributing factors, including infrastructure design, were common.

Safety-by-design can support drivers to make safe decisions when driving and so avoid crashes in the first instance. Self-explaining roads are an example of this design process. Conversely, the layout of a road environment can make driver error more likely.



Criteria for the assessment of road environments to be classified as risky by design

In combination with a high posted speed limit (80 km/h or higher), crash sites with one or more of the following criteria were defined as presenting an in-built, ever-present latent infrastructure risk where driver decision-making and the exercise of *Normal Driving* is not supported:

1. Adverse or compromised road geometry impacting driver sightlines. This includes instances of lanes or roads converging at offset angles (irrespective of line markings), narrow width turn-off / exit lane(s), or other fixed hazards.
2. The presence of crests or dips in midblock sections, or on approach to intersections in midblock environments.
3. Narrow lanes with no, narrow, or poor-quality shoulder(s), with or without unprotected roadside objects (on straight or curve).
4. Misleading line markings combined with other road geometry flaws (e.g., crest) on approach to intersections.
5. Poorly delineated intersection. Indicated by inadequate and/or poorly placed traffic control signals or traffic control signs, and/or absent line markings, the negative effects of which are exacerbated by the natural terrain of the intersection location.
6. Insufficient infrastructure control of turn lanes to avoid cross-traffic manoeuvre (i.e., lack right-turn arrow).
7. Poor quality road surfaces with adverse camber or alignment on high-speed curves.
8. Absent or poorly placed advisory signs at midblock locations.



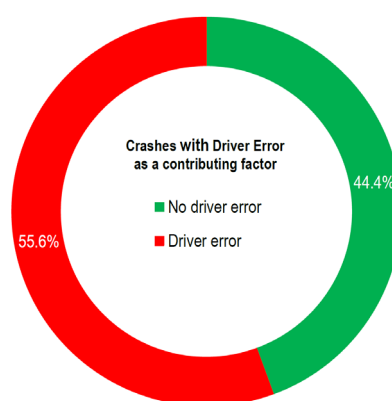
Driver error was more common at locations where latent infrastructure risk was identified

At 22% of locations where an ECIS crash occurred, one or more adverse design features in combination with a high-speed zone was evident. By meeting this criterion, these locations were classified as being inherently risky for drivers to make a safe decision. These locations are said to represent an in-built, or latent infrastructure, design risk for drivers.

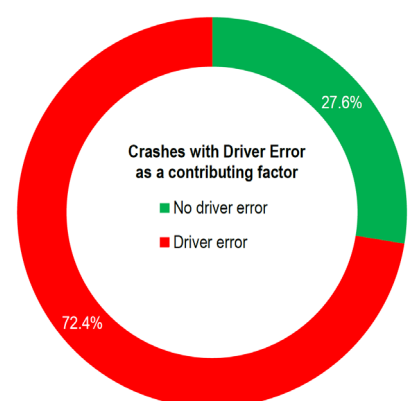
Driver error was a contributing factor in 72.4% of crashes at locations where this in-built design risk was present compared to 55.6% of crashes at locations where this design risk was absent.

Statistically, the risk of a driver making an error at locations where a latent infrastructure risk was identified was 58.7% higher than locations where no in-built design risk was present ($p \leq 0.01$).

No latent infrastructure risk



Latent infrastructure risk present



Implications

Road design and speed limits must account for the broad range of decision-making capabilities of drivers, especially at intersections. Supporting drivers to make safe and appropriate decisions is a key responsibility of road designers.

Active vehicle safety systems, such as cross-traffic alert, have potential to aid driver decision-making; however, the efficacy of these driver warning technologies is dependent on early detection of on-coming vehicles and on appropriate driver response.

MUARC ECIS Fact Sheet 5: Injuries sustained by ECIS drivers and associated financial costs and impacts^{1 2}

400 drivers (48.9% male; 51.1% female) aged 18 – 93 years were enrolled to the ECIS program following admission to either The Alfred Hospital or the Royal Melbourne Hospital for the treatment of injuries sustained in a crash.

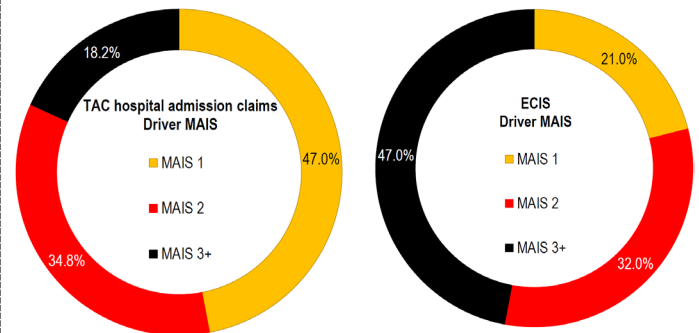
Using medical records, all validated driver injuries were classified according to the Association for the Advancement of Automotive Medicine (AAAM) Abbreviated Injury Scale (AIS) scoring system³, per best practice.

The AIS dictionary classifies all possible injuries by body region, rating each using a severity scale ranging from 1 (minor) to 6 (maximal). The highest severity injury is referred to as the maximum AIS (MAIS) severity level for the person. ECIS defined ‘serious injury’ as any injury having an AIS severity rating of 3 (serious) or higher (i.e., MAIS 3+).

Other injury metrics were also assessed and calculated, including the estimated financial cost to the Transport Accident Commission (TAC) to support the injured driver and wider financial costs to the community.

A high proportion of hospitalised drivers sustained serious (MAIS 3+) injuries, with many drivers sustaining multiple injuries across different parts of their body.

47% of drivers enrolled to the ECIS program in hospital sustained MAIS 3+ injuries. ECIS crashes were more severe than was the case for all hospitalised driver TAC clients (MAIS 3+: 18.2%). The findings of the ECIS program, for the main, reflect the more seriously injured part of the road trauma spectrum.



Key injury facts

Types and severity of injuries sustained (examples)

Drivers sustained multiple, serious injuries, for instance:

- 6.8% of drivers sustained MAIS 3+ injuries to the head (e.g., loss of consciousness > 1 hour, skull fracture).
- 27.8% of drivers sustained MAIS 3+ injuries to the chest (e.g., multiple rib fractures, lung injury, laceration of artery).
- 15.8% sustained MAIS 3+ injuries to the lower extremity (e.g., fractured femur, fractured pelvis).

Drivers required extended time in hospital, ranging from 1 to 43 days (mean: 8.6 days), with 16% in hospital for more than 14 days.

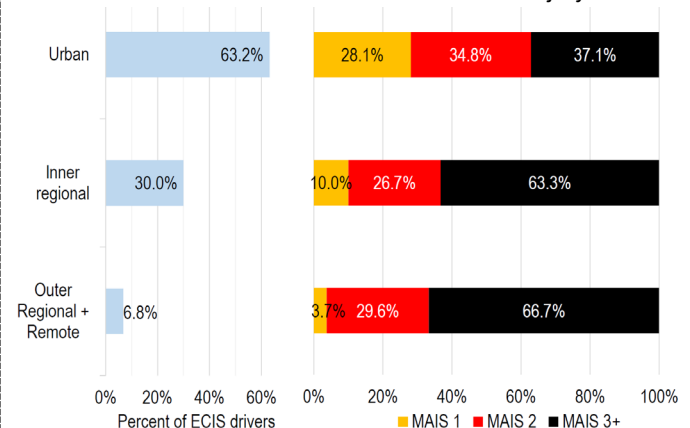
Extended care at a rehabilitation centre was needed by 41.5% of drivers following their acute care stay. Two-thirds of drivers with an MAIS 3+ injury required rehabilitation care.

Injury severity differed by crash type, with Lane Departure crashes being especially severe (MAIS 3+: 57%), followed by Across Path (MAIS 3+: 44%) and Rear Impact crashes (19%).

Crashes in regional Victoria were especially severe

Two-thirds of drivers involved in crashes in inner regional (63.3%) and outer regional (66.7%) locations in Victoria sustained MAIS 3+ severity injuries.

These drivers represented 36.8% of the ECIS driver sample but accounted for half of all drivers with an MAIS 3+ injury.



Crashes represent an immense financial burden to the community

Financial costs differ by crash type and reflect the level of injury suffered by drivers, with costs associated with Lane Departure crashes being especially high (\$945,600, mean value).

Calculation of costs account for head injury severity and spinal cord injury. Costs reflect medical costs, on-going care, vehicle costs, broader health, and loss of productivity costs.

ECIS DRIVER MAIS SEVERITY	PERCENT DRIVERS (OF 400)	COST FOR ECIS DRIVER (\$AUD, MILLION)	PERCENT COST	MEAN COST FOR ECIS DRIVER (\$AUD)
MAIS 1	21.0%	\$16.5	5.8%	\$196,538
MAIS 2	32.0%	\$47.7	16.7%	\$372,609
MAIS 3+	47.0%	\$220.9	77.5%	\$1,175,094
All	100%	\$285.1	100%	\$712,802

Implications

Drivers enrolled to the ECIS program sustained numerous injuries, many classified as ‘serious’ and more severe according to the widely used AIS injury severity scoring system. Many drivers required urgent and extensive surgical intervention and on-going care in a rehabilitation centre.

The financial costs associated with these crashes, both from an individual perspective and a community perspective, were high. Injured persons also face extensive recovery time, both physically and mentally.

The findings of the ECIS program highlight the severe nature of road crashes. The prevention of these crashes and the elimination of serious injury is urgent. Using the extensive data collected, the ECIS program identified key risk factors and countermeasures by which this goal can be achieved.

1 Fitzharris, M, Lenné, MG, Corben, B, Pok Arundell, T, Peiris, S, Liu, S, Stephens, A, Fitzgerald, M, Judson, R, Bowman, D, Gabler, C, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 1: Overview and Analysis of Crash Types, Injury Outcomes and Contributing Factors. Melbourne Vic Australia: Monash University, 2020. <https://www.monash.edu/muarc/ecis>

2 Fitzharris, M, Corben, B, Lenné, MG, Liu, S, Peiris, S, Pok Arundell, T, Bowman, D, Morris, A & Tingvall. Enhanced Crash Investigation Study (ECIS): Report 3: Understanding contributing factors for serious injury using crash chain analysis. Melbourne Vic Australia: Monash University, 2022. <https://www.monash.edu/muarc/ecis>

3 Association for the Advancement of Automotive Medicine (AAAM). Abbreviated Injury Scale (AIS) 2005 – Update 2008. Chicago: AAAM; 2015.